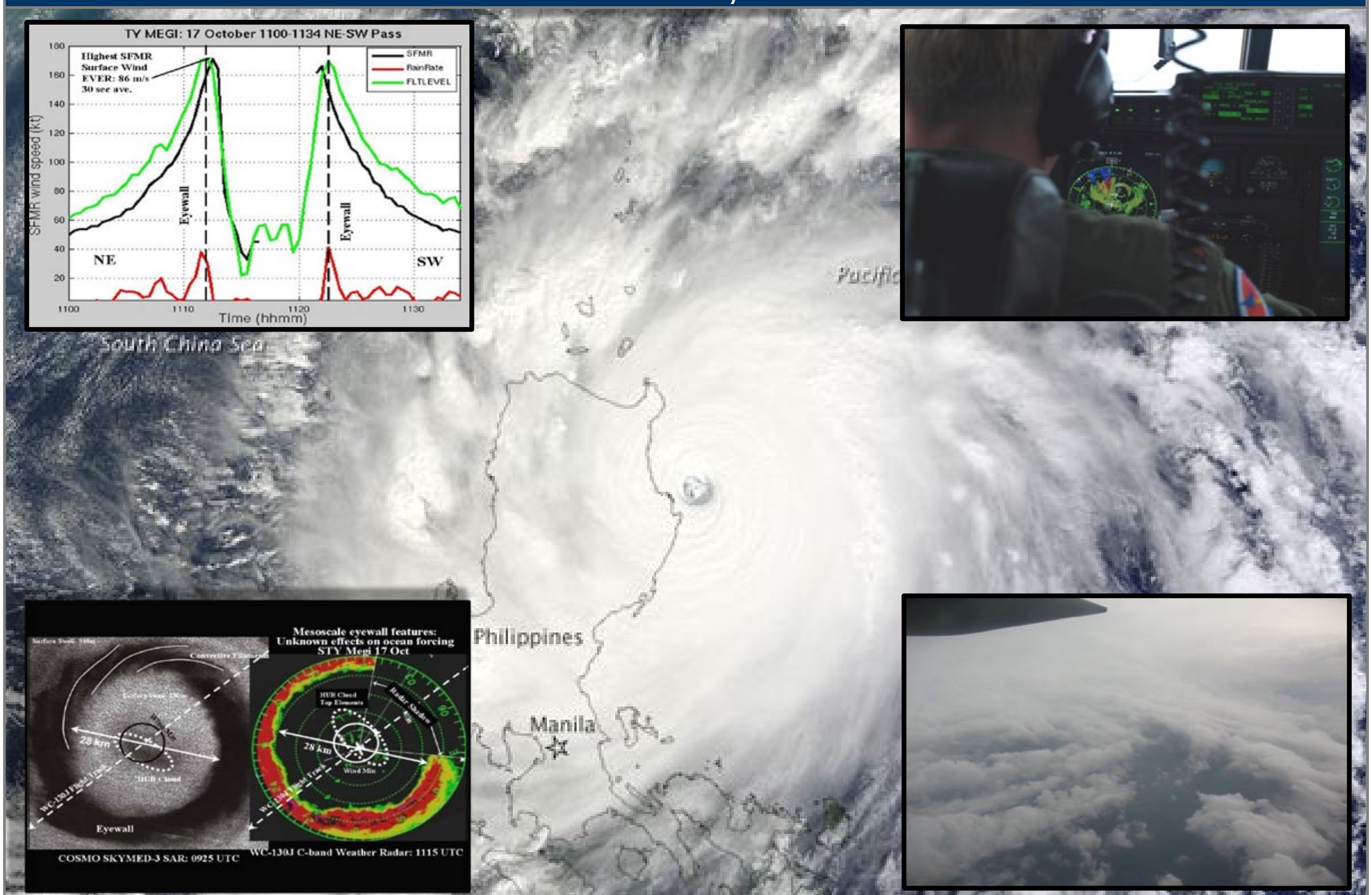
Annual Tropical Cyclone Report
2010

U.S. Naval Maritime Forecast Center/ Joint Typhoon Warning Center
Pearl Harbor, Hawaii



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Cover: Terra (EOS AM-1) spacecraft visible image of Super Typhoon Megi (15W), courtesy of NASA Earth Observatory. Inset images provided by JTWC Typhoon Duty Officers and other participants of the multi-national field campaign **Impact of Typhoons on the Ocean in the Pacific** (ITOP)/**Tropical Cyclone Structure 2010** (TCS-10): Dr. Peter Black, NRL Monterey (top & lower left), Richard Ballucanag (top right), and Matthew Kucas (lower right).

Executive Summary

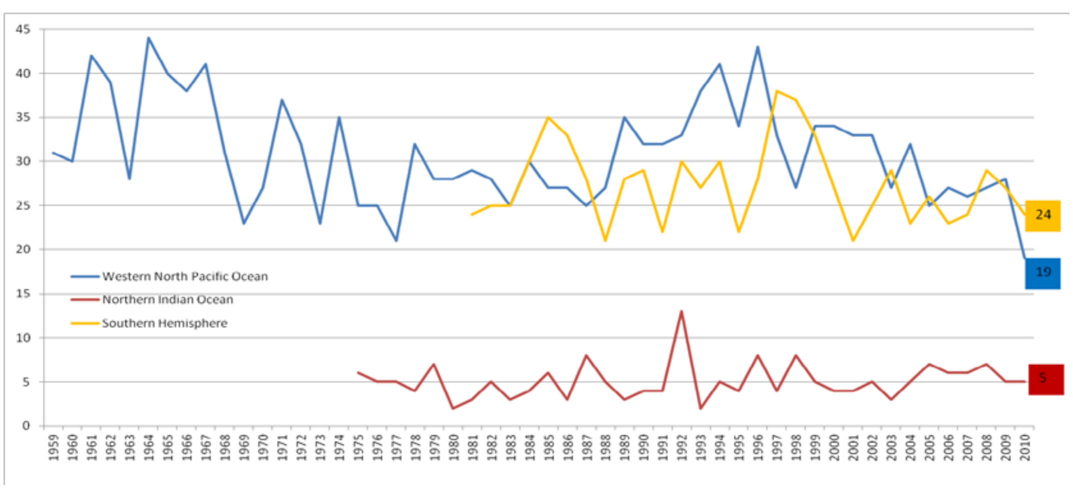
The Annual Tropical Cyclone Report (ATCR) is prepared by the staff of the Joint Typhoon Warning Center (JTWC), a jointly manned United States Air Force/Navy organization under the operational command of the Commanding Officer, Naval Maritime Forecast Center/Joint Typhoon Warning Center (NMFC/JTWC), Pearl Harbor, Hawaii.

JTWC was established on 1 May 1959 when Commander-in- Chief, US Pacific Command (USCINCPAC) directed Commander-in-Chief, Pacific Fleet to provide a single tropical cyclone warning center for the western North Pacific region. A subsequent USCINCPAC directive further tasked Commander, Pacific Air Force to provide for tropical cyclone (TC) reconnaissance support to the JTWC. Currently, JTWC operations are guided by USPACOM Instruction 0539.1 and Pacific Air Forces Instruction 15-101.

This edition of the ATCR documents the TC season and details operationally or meteorologically significant cyclones noted within the JTWC Area of Responsibility. Details are provided to describe either significant challenges and/or shortfalls in the TC warning system and to serve as a focal point for future research and development efforts.

Record low tropical cyclone activity was observed in the western North Pacific Ocean, continuing a trend that started in 2005, with only 19 TCs observed compared to the long term average of 31. Super Typhoon Megi (15W) was the only cyclone to reach super typhoon intensity. Megi was a significant cyclone because it occurred during the Office of Naval Research sponsored Impact of Typhoons on the Pacific/Tropical Cyclone Structure 2010 (ITOP/TCS-10) field campaign. Megi was penetrated by United States Air Force Reserve WC-130J reconnaissance aircraft. During one of these penetrations, the Step Frequency Microwave Radiometer (SFMR) measured the highest tropical cyclone wind speed ever recorded, 86 m/s (172 kts). Typhoon Kompasu (08W) was operationally significant because it made landfall on Okinawa as a strong typhoon and on South Korea as a minimal typhoon.

The Southern Hemisphere activity was also below normal, with 24 cyclones observed compared to an average of 28 and the North Indian Ocean experienced normal activity with 5 cyclones. Tropical Cyclones Phet and Giri were notable cyclones in the Arabian Sea and Bay of Bengal, respectively. Phet underwent rapid intensification off the coast of Oman, then moved across the eastern part of the country, into the Gulf of Oman and then into Pakistan. Giri also underwent rapid intensification just prior to making landfall in Myanmar. Both cyclones resulted in USPACOM directed Humanitarian Assistance/Disaster Relief responses.



Annual number of tropical cyclones across the JTWC AOR

The ITOP/TCS-10 field campaign, aimed at assessing the impacts typhoons have on the ocean, brought significantly enhance observations to the western North Pacific during the months of August, September and early October. Additionally, it provided an opportunity for Typhoon Duty Officer qualified personnel, Mr. Matt Kucas, Mr. Rick Ballucanag, and LT Chris Morris to fly on the WC-130J as mission scientists.

During 2010, NMFC/JTWC continued funding upgrades to the Geophysical Fluid Dynamics Lab-Navy (GFDN) tropical cyclone following mesoscale model. These upgrades included both physics updates and 3-dimensional air-ocean coupling for the Indian Ocean and the Southern Hemisphere.

Weather satellite data remained the mainstay of the TC reconnaissance mission at the JTWC. Satellite analysts exploited a wide variety of conventional and microwave satellite data to produce over 7,770 position and intensity estimates (fixes), primarily using the USAF Mark IVB and the USN FMQ-17 satellite direct readout systems. The Mark IVB began receiving an upgraded capability to receive and process X-band signals, providing real-time access to the Aqua and Terra satellites. The JTWC also continued to use geo-located microwave satellite imagery overlays available via the Automated Tropical Cyclone Forecast (ATCF) system from Fleet Numerical Meteorology and Oceanography Center and the Naval Research Lab Monterey to make TC fixes. JTWC continued to advocate for improved satellite reconnaissance capability, including continuation of the Navy Research Labs Coriolis/WindSAT, an ocean surface vector wind capable 43 channel microwave sensor on the Defense Weather Satellite System (DWSS), and exploitation of international remote sensing capabilities, including the Indian Space Research Organizations OceanSAT-2 and the joint Meteo France / Indian Mega Tropiques.

JTWC continued to collaborate with TC forecast support and research organizations such as the Fleet Numerical Meteorology and Oceanography Center (FNMOC), Naval Research Laboratory, Monterey (NRLMRY), Naval Post Graduate School, the Office of Naval Research, and Air Force Weather Agency (AFWA) for continued development of numerical TC models and forecast aids. Operational support and enhancements to the ATCF system continued, making development and issuance of tropical cyclone warnings as streamlined as possible for forecasters.

Additionally, in an effort to provide greater support to assets in the southern hemisphere and the northern Indian Ocean, JTWC extended warning periods in 2010 from 72hrs to 120hrs for those basins; providing 5-day forecasts to enhance resource protection for the entire JTWC AOR.

Behind all these efforts are the dedicated team of men and women, military and civilian at NMFC/JTWC. Special thanks to the entire N6 Department for their outstanding IT support and the administrative and budget staff who worked tirelessly to ensure JTWC had the necessary resources to get the mission done.

Special thanks also to: FNMOC for their operational data and modeling support; the NRLMRY and ONR for its dedicated research; the National Oceanic and Atmospheric Administration National Environmental Satellite, Data, and Information Service for satellite support; for their high quality support; all the men and women of the ships and facilities ashore throughout the JTWC area of responsibility; Dr. John Knaff, Mr. Jeff Hawkins, Dr. Mark DeMaria, and Mr. Chris Velden for their continuing efforts to exploit remote sensing technologies in new and innovative ways; Mr. Charles R. “Buck” Sampson, Ms. Ann Schrader, Mr. Mike Frost, and Mr. Chris Sisko for their support and continued development of the ATCF system.

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Chapter 1 Western North Pacific Ocean Tropical Cyclones

Section 1 Informational Tables

Table 1-1 is a summary of tropical cyclone (TC) activity in the western North Pacific Ocean during the 2010 season. JTWC issued warnings on 19 cyclones. Table 1-2 shows the monthly distribution of TC activity summarized for 1959 - 2010 and Table 1-3 shows the monthly average occurrence of TC's separated into: (1) typhoons and (2) tropical storms and typhoons. Table 1-4 summarizes Tropical Cyclone Formation Alerts issued. The annual number of TC's of tropical storm strength or higher appears in Figure 1-1, while the number of TC's of super typhoon intensity appears in Figure 1-2. Figure 1-3 illustrates a monthly average number of cyclones based on intensity categories. Graphics showing 2010 tropical cyclone best tracks appear following Figure 1-3.

Table 1-1

WESTERN NORTH PACIFIC SIGNIFICANT TROPICAL CYCLONES FOR 2010
(01 JAN 2010 - 31 DEC 2010)

TC	NAME*	PERIOD**	WARNINGS ISSUED	EST MAX SFC WINDS KTS	MSLP (MB)***
TD 01W		18-19 JAN	5	30	1000
TS 02W	OMAIS	21-26 MAR	19	50	985
TY 03W	CONSON	11-17 JUL	26	80	963
TY 04W	CHANTHU	18-22 JUL	18	80	963
TS 05W	DIANMU	8-12 AUG	17	55	982
TY 06W	MINDULLE	22-24 AUG	10	65	974
TS 07W	LIONROCK	27 AUG- 02 SEP	24	60	978
TY 08W	KOMPASU	28 AUG-02 SEP	20	105	944
TS 09W	NAMTHEUN	30 AUG-01 SEP	8	40	993
TS 10W	MALOU	01-07 SEP	24	45	989
TY 11W	MERANTI	08-10 SEP	9	65	974
TY 12W	FANAPI	14-20 SEP	23	105	944
TY 13W	MALAKAS	20-25 SEP	20	90	956
TD 14W		05-06 OCT	5	30	1000
STY 15W	MEGI	13-23 OCT	42	160	903
TY 16W	CHABA	21-30 OCT	37	115	937
TD 17W		21 - 23 OCT	8	30	1000
TD 18W		12-14 NOV	6	25	1004
TD 19W		12-13 DEC	4	25	1004

* As designated by the responsible RSMC

** Dates are based on the issuance of JTWC warnings on system.

***MSLP converted from estimated maximum surface winds using Knaff-Zehr wind-pressure relationship.

Table 1-2
DISTRIBUTION OF WESTERN NORTH PACIFIC TROPICAL CYCLONES FOR 1959 - 2010

YEAR	JAN			FEB			MAR			APR			MAY			JUN			JUL			AUG			SEP			OCT			NOV			DEC			TOTALS		
1959	0			1			1			1			0			1			3			8			9			3			2			2			31		
	0	0	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0	1	1	1	1	5	1	2	4	2	3	2	1	0	2	0	0	2	0	0	17	7	7
1960	1			0			1			1			1			3			3			9			5			4			1			1			120		
	0	0	1	0	0	0	0	0	1	1	0	0	0	1	0	2	1	0	2	1	0	8	1	0	0	4	1	4	0	0	1	0	0	1	0	0	19	8	3
1961	1			1			1			1			4			6			5			7			6			7			2			1			42		
	0	1	0	0	1	0	1	0	0	0	1	0	2	1	1	1	1	4	3	2	0	3	1	3	5	1	0	3	2	2	1	0	1	1	0	0	20	11	11
1962	0			1			0			1			3			0			8			8			7			5			4			2			39		
	0	0	0	0	1	0	0	0	0	1	0	0	2	0	1	0	0	0	5	1	2	7	0	1	3	1	3	3	1	1	3	0	1	0	2	0	24	6	9
1963	0			0			1			1			0			4			5			4			4			6			0			3			28		
	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	3	1	0	3	1	1	3	0	1	2	2	0	5	1	0	0	0	0	2	1	0	19	6	3
1964	0			0			0			0			3			2			8			8			8			7			6			2			44		
	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	2	0	0	6	1	1	3	5	0	5	2	1	3	3	1	4	2	0	1	0	1	26	13	5
1965	2			2			1			1			2			4			6			7			9			3			2			1			40		
	1	1	0	0	2	0	0	1	0	1	0	0	1	0	1	3	1	0	4	1	1	3	2	2	5	3	1	2	0	1	1	1	0	0	1	0	21	13	6
1966	0			0			0			1			2			1			4			9			10			4			5			2			38		
	0	0	0	0	0	0	0	0	0	1	0	0	2	0	0	1	0	0	3	1	0	5	3	1	5	3	2	1	1	2	1	2	2	1	0	1	20	10	8
1967	1			0			2			1			1			1			8			10			8			4			4			1			41		
	0	1	0	0	0	0	1	1	0	1	0	0	0	1	0	1	0	0	3	3	2	3	4	3	5	3	0	2	1	1	4	0	0	0	1	0	20	15	6
1968	0			1			0			1			0			4			3			8			4			6			4			0			31		
	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	2	0	2	1	2	0	3	4	1	4	0	0	5	1	0	4	0	0	0	0	0	20	7	4
1969	1			0			1			1			0			0			3			3			6			5			2			1			23		
	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	2	1	0	2	1	0	2	0	4	4	1	0	1	1	0	0	1	0	13	6	4
1970	0			1			0			0			0			2			3			7			4			6			4			0			27		
	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	1	4	2	1	2	2	0	3	2	1	1	3	0	0	0	0	12	12	3
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	0	1	0	0	0	0	0	1	0	2	0	0	2	3	0	2	0	0	6	2	0	3	1	1	5	1	1	3	1	0	1	1	0	0	0	0	24	11	2
1972	1			0			1			0			0			4			5			5			6			5			2			3			32		
	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2	2	0	4	1	0	3	2	0	4	1	1	4	1	0	2	0	0	2	1	0	22	8	2
1973	0			0			0			0			0			0			7			6			3			4			3			0			23		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	3	0	2	3	1	2	0	1	4	0	0	0	3	0	0	0	0	12	9	2
1974	1			0			1			1			1			4			5			7			5			4			4			2			35		
	0	1	0	0	0	0	0	1	0	0	1	0	1	0	0	1	2	1	2	3	0	2	3	2	3	2	0	4	0	0	2	2	0	0	2	0	15	17	3
1975	1			0			0			1			0			0			1			6			5			6			3			2			25		
	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	4	1	1	4	1	0	3	2	1	2	1	0	0	2	0	14	8	5
1976	1			1			0			2			2			2			4			4			5			0			2			2			25		
	1	0	0	0	1	0	0	0	0	1	1	0	2	0	0	2	0	0	2	2	0	1	3	0	4	1	0	0	0	0	1	1	0	0	2	0	14	11	10
1977	0			0			1			0			1			1			4			2			5			4			2			1			21		
	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	3	0	1	0	2	0	2	3	0	3	1	0	2	0	0	1	0	0	11	8	2
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	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	3	0	3	1	0	3	4	1	3	1	0	4	1	2	1	2	1	0	0	0	15	13	4
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1991	0			0			2			1			1			1			4			8			6			3			6			0			32		
	0	0	0	0	0	0	1	1	0	0	1	0	1	0	0	1	0	100	4	0	0	3	3	2	4	2	0	3	0	0	3	3	0	0	0	0	20	10	2
1992	1			1			0			0			0			3			4			8			5			6			5			0			33		
	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	1	0	2	2	0	4	4	0	4	1	0	5	1	0	3	1	1	0	0	0	21	11	11
1993	0			0			2			2			1			2			5			8			5			6			4			3			38		
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1994	1			0			1			0			2			2			9			9			8			7					0	2			41		
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1995	1			0			0			0			1			2			3			7			7			8			2			3			34		
	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	2	1	0	4	2	1	4	1	2	5	1	2	0	2	0	0	1	2	15	11	8
1996	1			1			0			2			2			0			7			10			7			5			6			3			44		
	0	0	1	0	0	1	0	0	0	0	1	1	1	1	0	0	0	0	6	1	0	4	3	3	6	1	0	2	1	2	1	3	2	1	1	1	21	12	10
1997	1			0			0			2			3			3			4			8			4			6			1			1			33		
	0	1	0	0	0	0	0	0	0	1	1	0	1	2	0	3	0	0	3	1	0	6	1	1	3	1	0	4	1	1	1	0	0	1	0	0	23	8	2
1998	0			0			0			0			0			0			3			3			8			6			3			4			27		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	1	0	4	1	3	2	1	3	0	3	0	1	1	2	9	8	10
1999	1			1			0			3			0			1			5			9			6			2			3			3			34		
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2000	0			0			0			0			4			0			8			9			6			3			3			1			34		
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2001	0			1			0			1			1			2			6			7			5			3			3			4			33		
	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	2	0	0	4	1	1	3	3	1	5	0	0	3	0	0	1	2	0	2	2	0	20	9	4
2002	1			1			1					1	2			3			6			8			3			5			1			1			33		
	0	1	0	1	0	0	0	0	1	0	0	1	1	0	1	3	0	0	3	2	1	4	3	1	1	2	0	3	0	2	1	0	0	1	0	0	18	8	7
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2004	0			1			1			1			3			5			2			9			3			3			2			2			32		
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2005	1			0			1			1			0			1			4			6			5			3			2			1			25		
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2006	0			0			1			0			1			1			3			8			5			4			2			2			27		
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2007	0			0			1			0			1			0			3			5			5			5			6			0			26		
	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	2	1	0	3	2	1	2	2	1	3	2	0	3	1	2	0	0	0	15	8	4
2008	1			0			0			1			4			1			2			5			6			3			3			1			27		
	0	1	0	0	0	0	0	0	0	1	0	100	3	1	0	1	0	0	2	0	0	1	4	0	3	3	0	0	3	0	0	3	0	1	0	0	12	15	0
2009	0			0			0			0			2			2			3			5			7			4			4			1			28		
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2010	1			0			1			0			0			0			2			5				4		4			1			1			19		
	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	2	0	0	2	3	0	3	1	0	2	2	0	0	0	1	0	0	1	9	7	4

2) If a tropical cyclone was warned on prior to the last two days of a month, it was attributed to the first month, regardless of how long the system lasted.

3) If a tropical cyclone began on the last day of the month and ended on the first day of the next month, that system was attributed to the first month. However, if a tropical cyclone began on the last day of the month and continued into the next month for only two days, it was attributed to the second month.

Total month/year		
GTE 64 knots	34 to 63 knots	LTE 33 knots

TABLE 1-3 WESTERN NORTH PACIFIC TROPICAL CYCLONES													
TYPHOONS (1945 - 1958)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
MEAN	0.4	0.1	0.3	0.4	0.7	1.1	2	2.9	3.2	2.4	2	0.9	16.4
CASES	5	1	4	5	10	15	28	41	45	34	28	12	228
TYPHOONS (1959 - 2010)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
MEAN	0.2	0.1	0.2	0.4	0.8	1.1	2.5	3.5	3.3	3.0	1.6	0.7	17.3
CASES	11	3	10	23	39	56	131	182	172	154	81	35	897
TROPICAL STORMS AND TYPHOONS (1945 - 1958)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
MEAN	0.4	0.2	0.5	0.5	0.8	1.6	2.9	4	4.2	3.3	2.7	1.2	22.3
CASES	6	2	7	8	11	22	44	60	64	49	41	18	332
TROPICAL STORMS AND TYPHOONS (1959 - 2010)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
MEAN	0.5	0.2	0.4	0.7	1.2	1.7	3.9	5.6	4.9	4.0	2.6	1.3	26.9
CASES	25	12	23	34	61	88	202	293	255	210	133	65	1401

TABLE 1-4 TROPICAL CYCLONE FORMATION ALERTS FOR THE WESTERN NORTH PACIFIC OCEAN 1976 - 2010					
YEAR	INITIAL TCFAS	TROPICAL CYCLONES WITH TCFAS	TOTAL TROPICAL CYCLONES	PROBABILITY OF TCFA WITHOUT WARNING*	PROBABILITY OF TCFA BEFORE WARNING
1976	34	25	25	26%	100%
1977	26	20	21	23%	95%
1978	32	27	32	16%	84%
1979	27	23	28	15%	82%
1980	37	28	28	24%	100%
1981	29	28	29	3%	97%
1982	36	26	28	28%	93%
1983	31	25	25	19%	100%
1984	37	30	30	19%	100%
1985	39	26	27	33%	96%
1986	38	27	27	29%	100%
1987	31	24	25	23%	96%
1988	33	26	27	21%	96%
1989	51	32	35	37%	91%
1990	33	30	31	9%	97%
1991	37	29	31	22%	94%
1992	36	32	32	11%	100%
1993	50	35	38	30%	92%
1994	50	40	40	20%	100%
1995	54	33	35	39%	94%
1996	41	39	43	5%	91%
1997	36	30	33	17%	91%
1998	38	18	27	53%	67%
1999	39	29	33	26%	88%
2000	40	31	34	23%	91%
2001	34	28	33	18%	85%
2002	39	31	33	21%	94%
2003	31	27	27	13%	100%
2004	35	32	32	9%	100%
2005	26	25	25	4%	100%
2006	23	22	26	4%	85%
2007	27	26	27	4%	96%
2008	23	23	28	0%	82%
2009	26	22	28	15%	79%
2010	24	18	19	25%	95%
MEAN	34.9	27.6	29.8	21%	93%
CASES	1223	967	1042		
* Percentage of initial TCFAs not followed by warnings.					

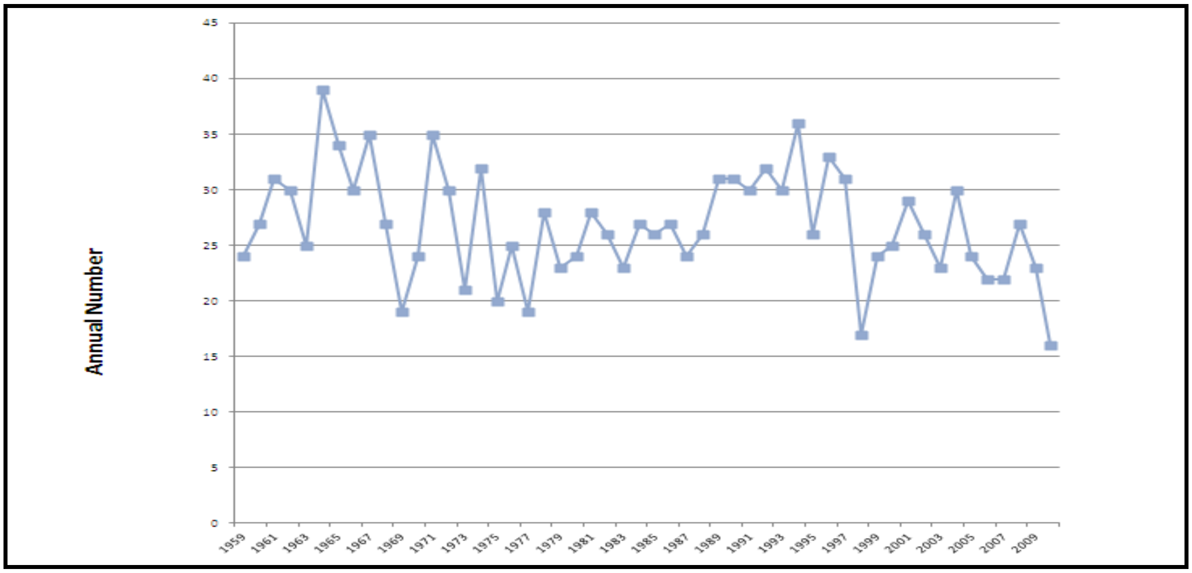


Figure 1-1. Annual number of Tropical Cyclones greater than 34 knots intensity.

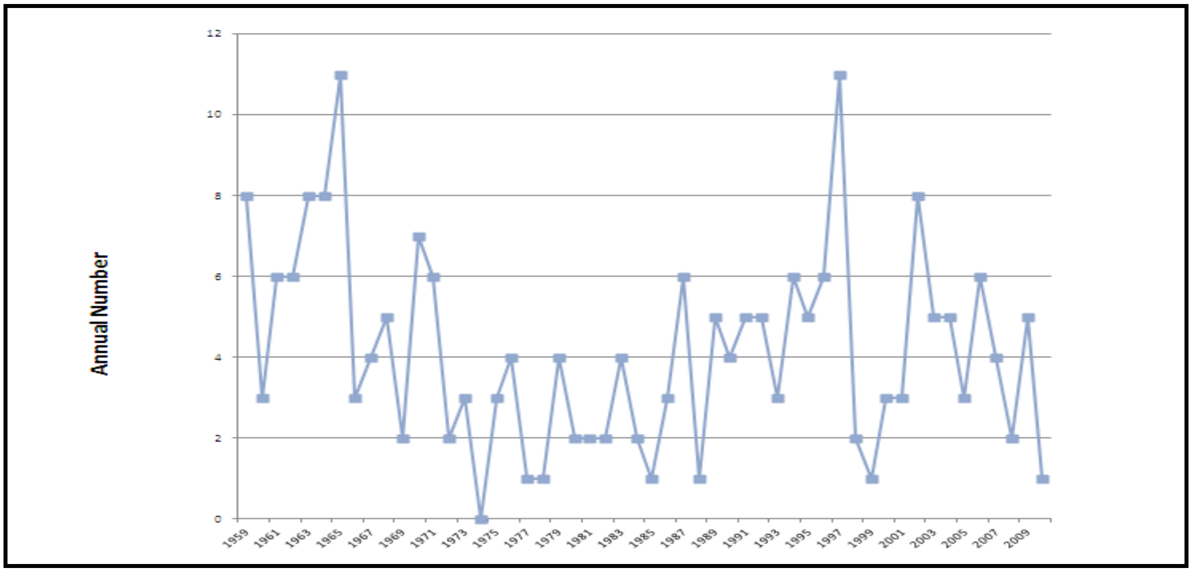
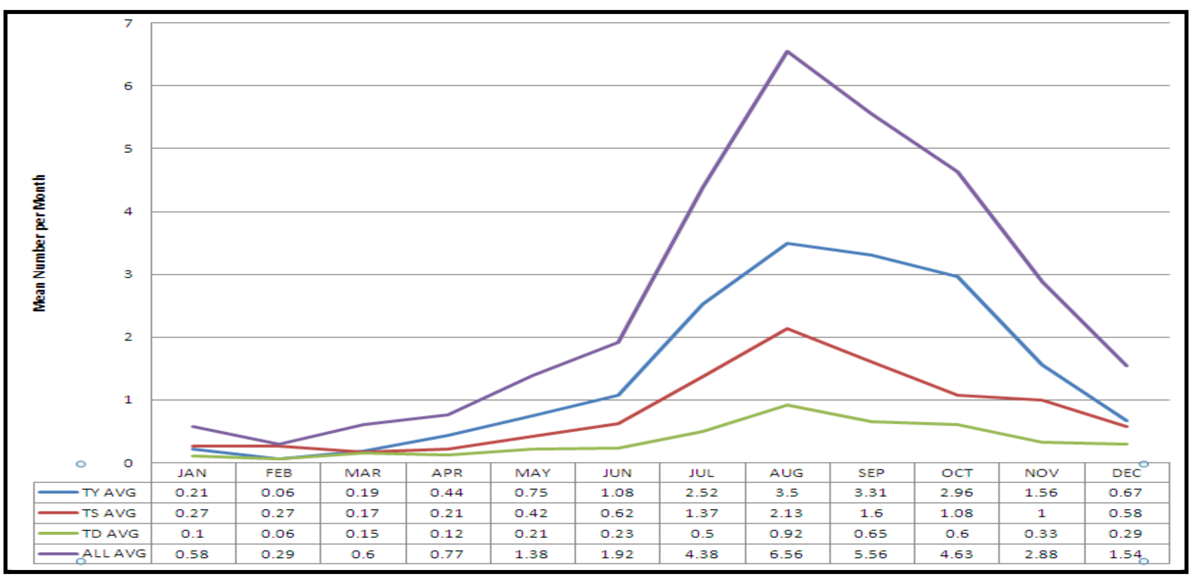


Figure 1-2. Annual number of Tropical Cyclones greater than 127 knots intensity.



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
TY AVG	0.21	0.06	0.19	0.44	0.75	1.08	2.52	3.5	3.31	2.96	1.56	0.67
TS AVG	0.27	0.27	0.17	0.21	0.42	0.62	1.37	2.13	1.6	1.08	1	0.58
TD AVG	0.1	0.06	0.15	0.12	0.21	0.23	0.5	0.92	0.65	0.6	0.33	0.29
ALL AVG	0.58	0.29	0.6	0.77	1.38	1.92	4.38	6.56	5.56	4.63	2.88	1.54

Figure 1-3. Average number of Tropical Cyclones of all intensities by month.

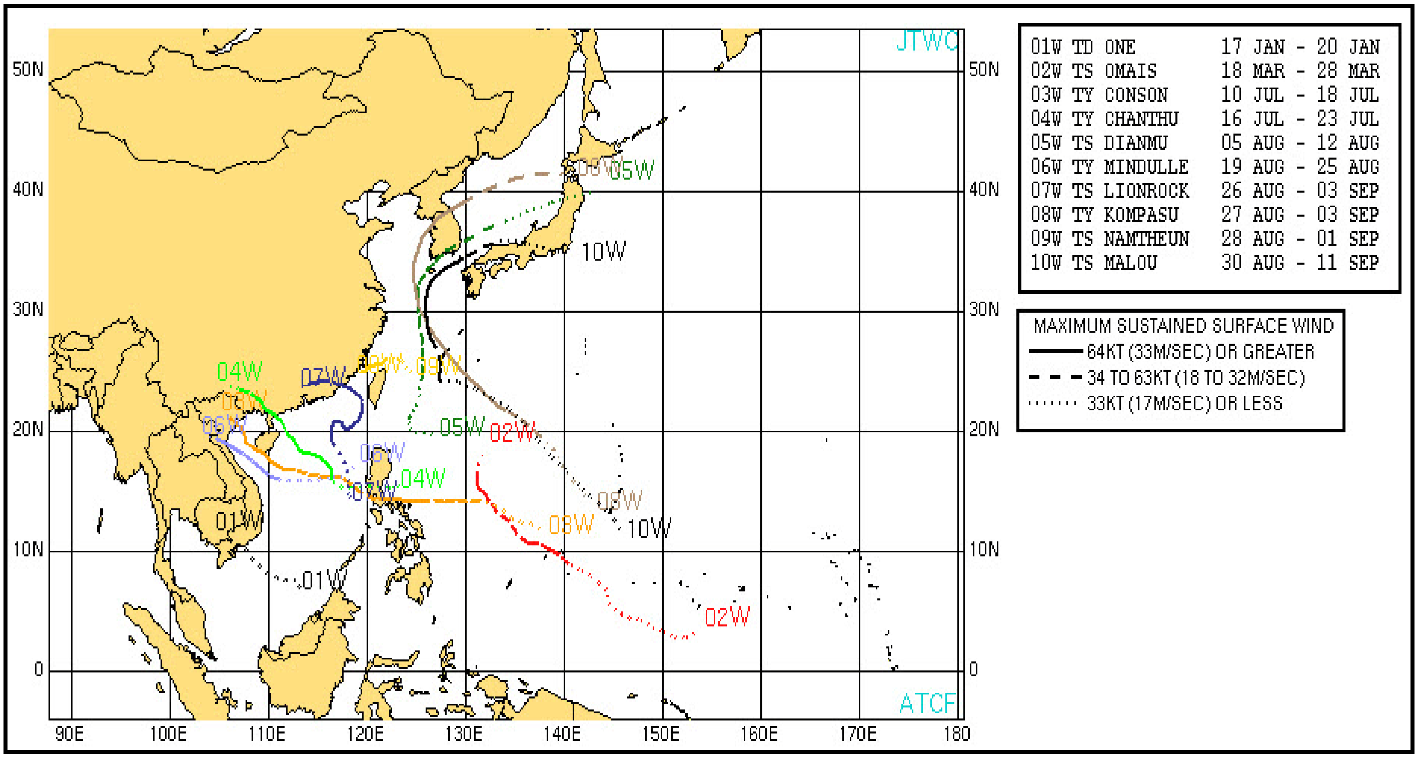


Figure 1-4. Western North Pacific Tropical Cyclones 01W – 10W.

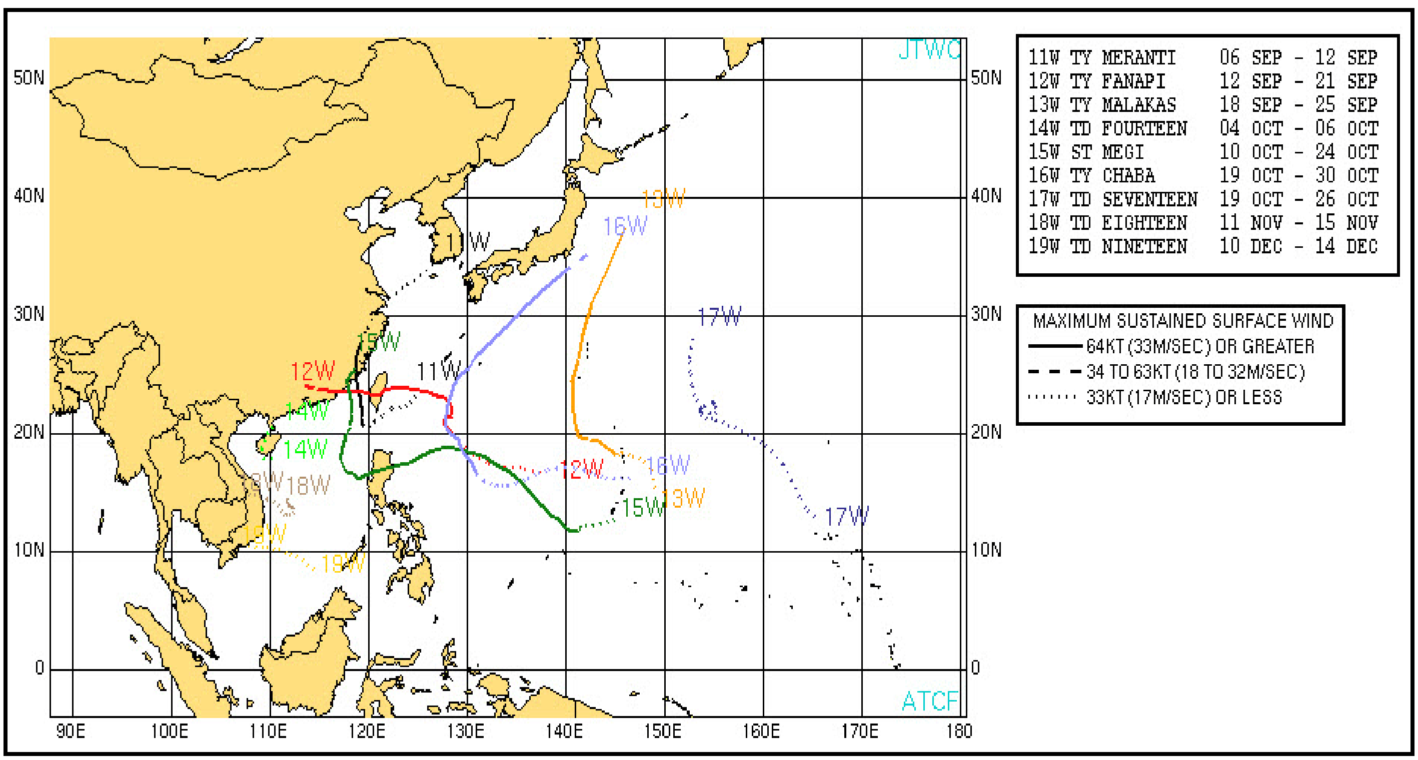


Figure 1-5. Western North Pacific Tropical Cyclones 11W – 19W.

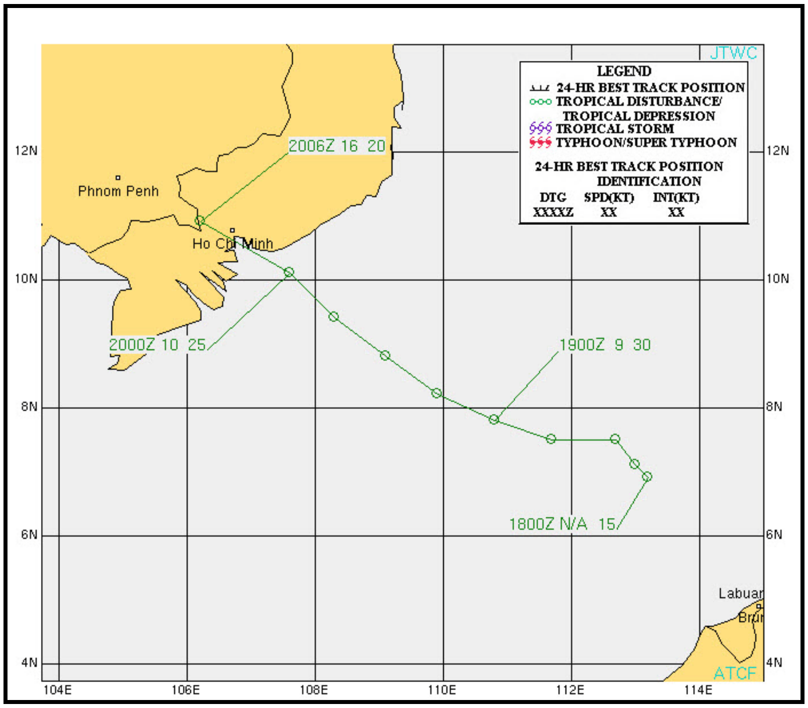
Section 2 Cyclone Summaries

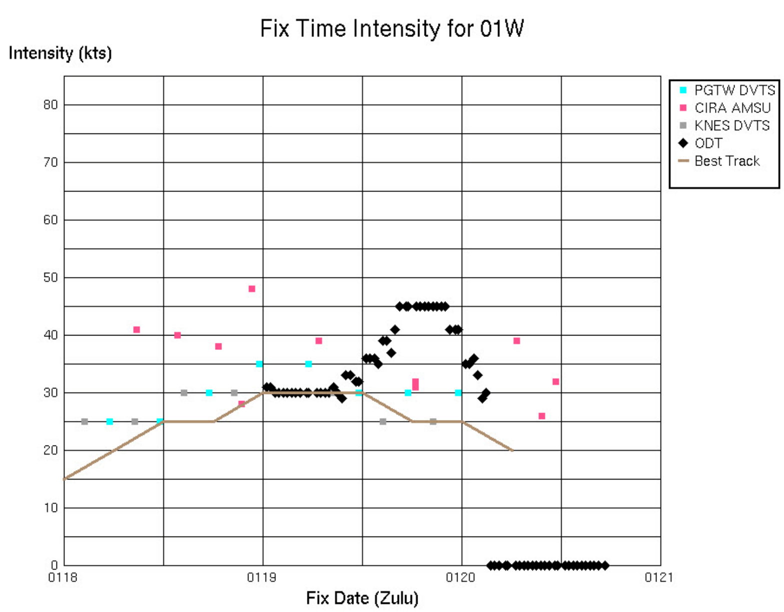
This section presents a synopsis of each cyclone that occurred during 2010 in the western North Pacific Ocean. Each cyclone is presented, with the number and basin identifier used by JTWC, along with the RSMC assigned name. Dates are also listed when JTWC first designated the various stages of development; as an area of interest (Poor classification), increased potential for development (Fair classification) and development occurring/TC expected (Good classification). Furthermore, the first Tropical Cyclone Formation Alert (TCFA) and the initial and final warning dates are also presented with the number of warnings issued by JTWC. Landfall over major landmasses with approximate locations is presented as well.

The JTWC post-event reanalysis best track is also provided for each cyclone. Data included on the best track are position and intensity noted with cyclone symbols and color coded track. Best track position labels include the date-time, track speed in knots, and maximum wind speed in knots. A graph of best track intensity and fix intensity versus time is presented. The fix plots on this graph are color coded by fixing agency.

Tropical Depression 01W

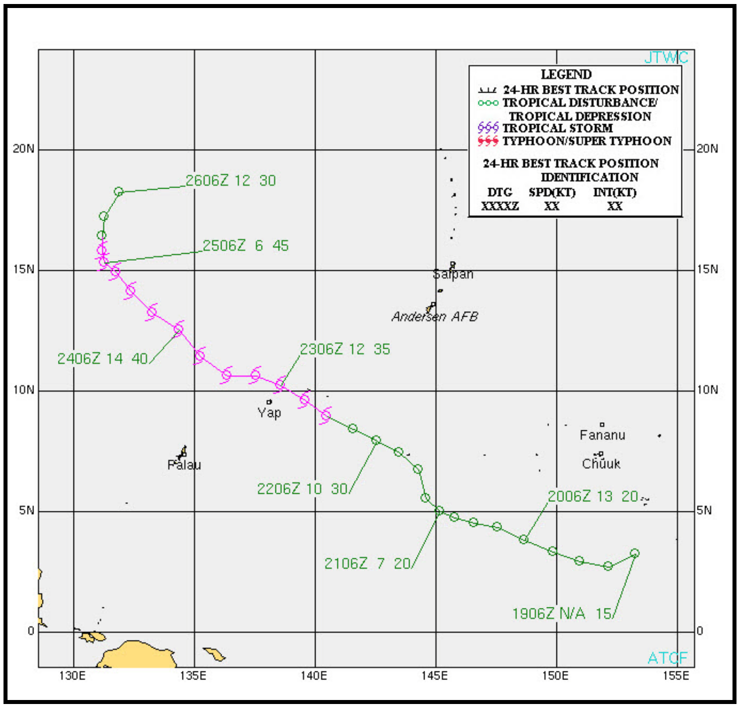
ISSUED POOR:	N/A
ISSUED FAIR:	1400Z 18 Jan 2010
FIRST TCFA:	N/A
FIRST WARNING:	1800Z 18 Jan 2010
LAST WARNING:	1800Z 19 Jan 2010
MAX INTENSITY:	30 Kts
NUMBER OF WARNINGS:	5

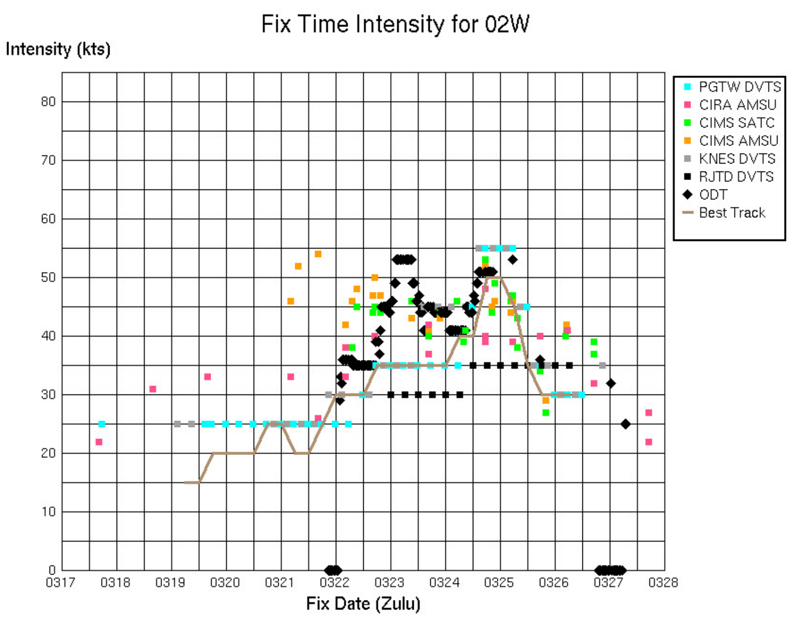




Tropical Storm 02W (Omais)

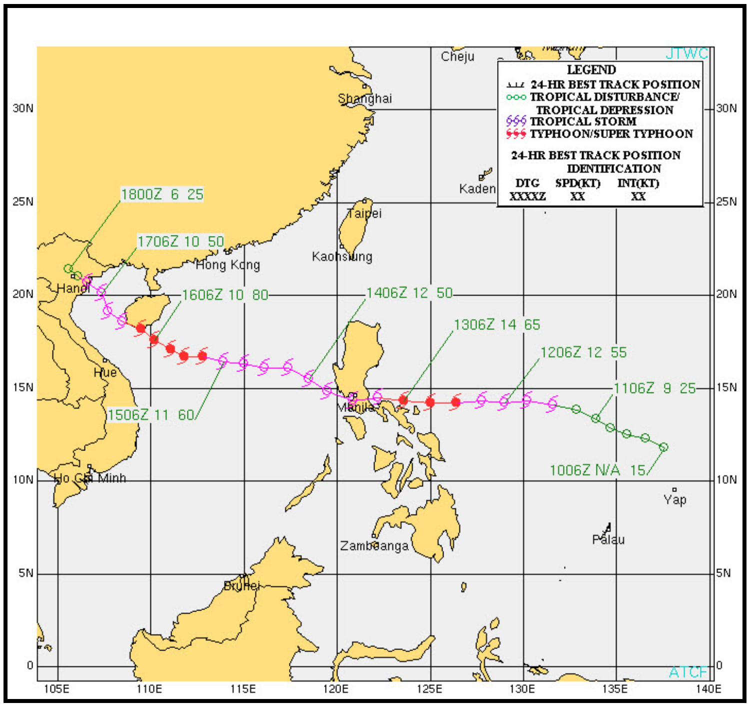
ISSUED POOR:	0600Z 18 Mar 2010
ISSUED FAIR:	0600Z 19 Mar 2010
FIRST TCFA:	2300Z 20 Mar 2010
FIRST WARNING:	1800Z 21 Mar 2010
LAST WARNING:	0600Z 26 Mar 2010
MAX INTENSITY:	50 Kts
NUMBER OF WARNINGS:	19

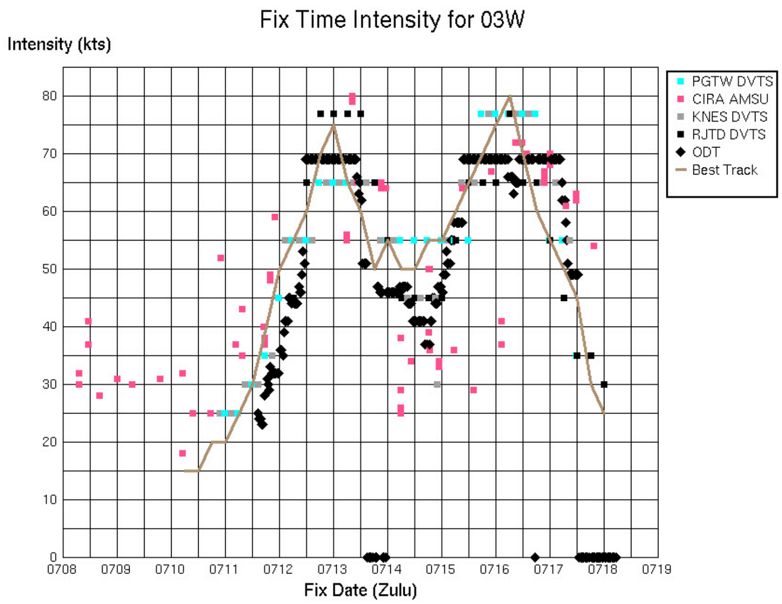




Typhoon 03W (Conson)

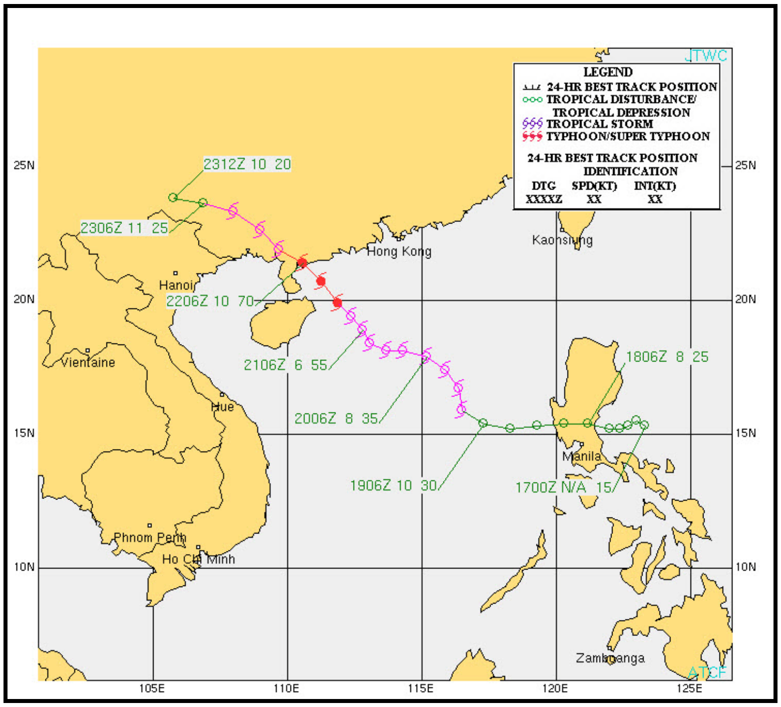
ISSUED POOR:	2130Z 09 Jul 2010
ISSUED FAIR:	2130Z 10 Jul 2010
FIRST TCFA:	0600Z 11 Jul 2010
FIRST WARNING:	1200Z 11 Jul 2010
LAST WARNING:	1800Z 17 Jul 2010
MAX INTENSITY:	80Kts
NUMBER OF WARNINGS:	26

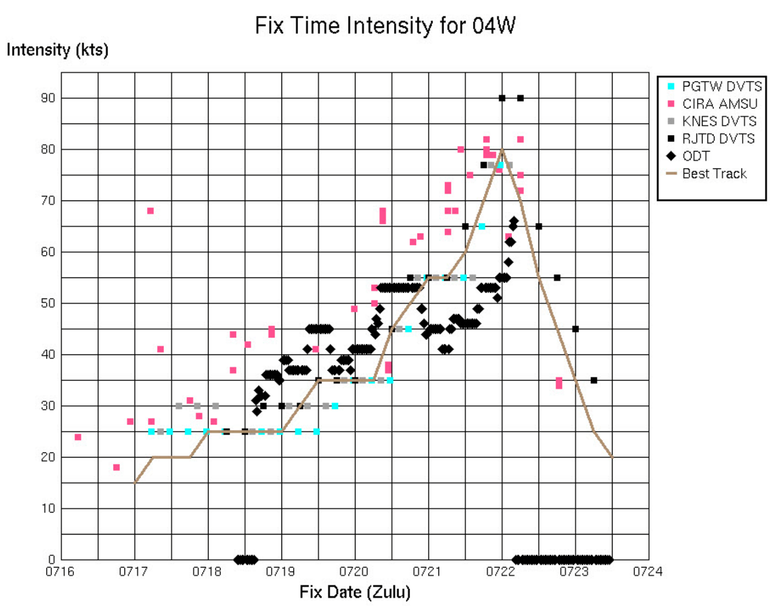




Typhoon 04W (Chanthu)

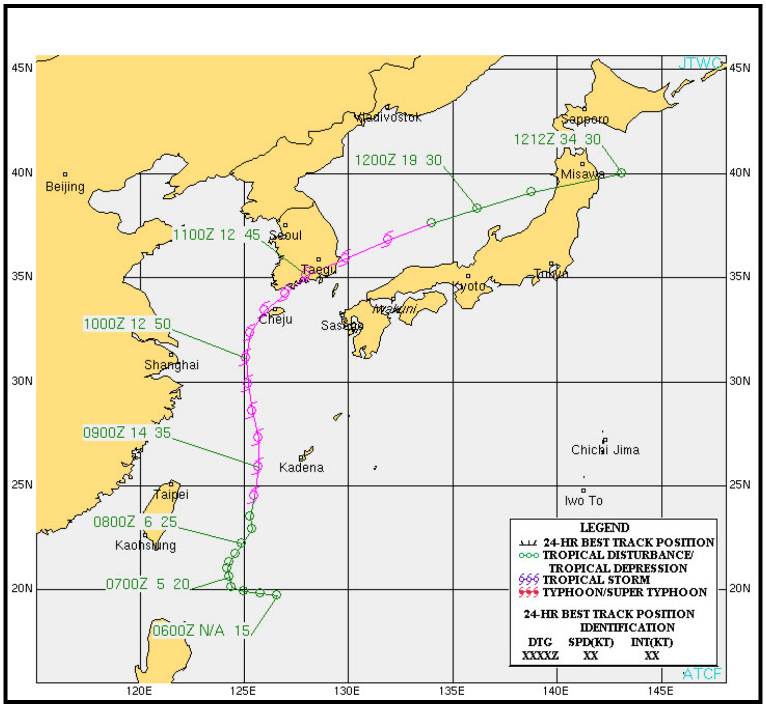
ISSUED POOR:	0600Z 17 Jul 2010
ISSUED FAIR:	1630Z 17 Jul 2010
FIRST TCFA:	0330Z 18 Jul 2010
FIRST WARNING:	0600Z 18 Jul 2010
LAST WARNING:	1800Z 22 Jul 2010
MAX INTENSITY:	80 Kts
NUMBER OF WARNINGS:	18

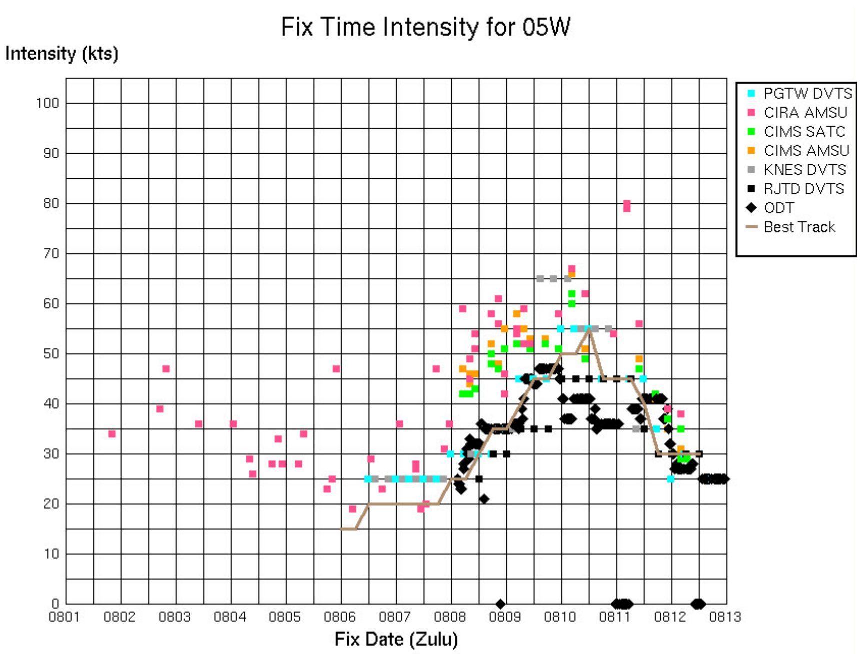




Tropical Storm 05W (Dianmu)

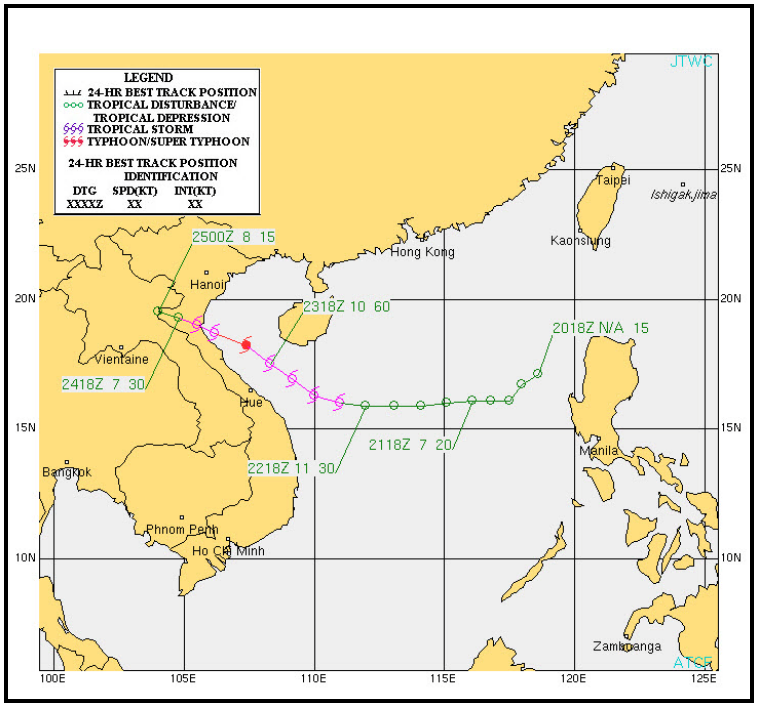
ISSUED POOR:	N/A
ISSUED FAIR:	1130Z 06 Aug 2010
FIRST TCFA:	0200Z 07 Aug 2010
FIRST WARNING:	0000Z 08 Aug 2010
LAST WARNING:	0000Z 12 Aug 2010
MAX INTENSITY:	55 Kts
NUMBER OF WARNINGS:	17



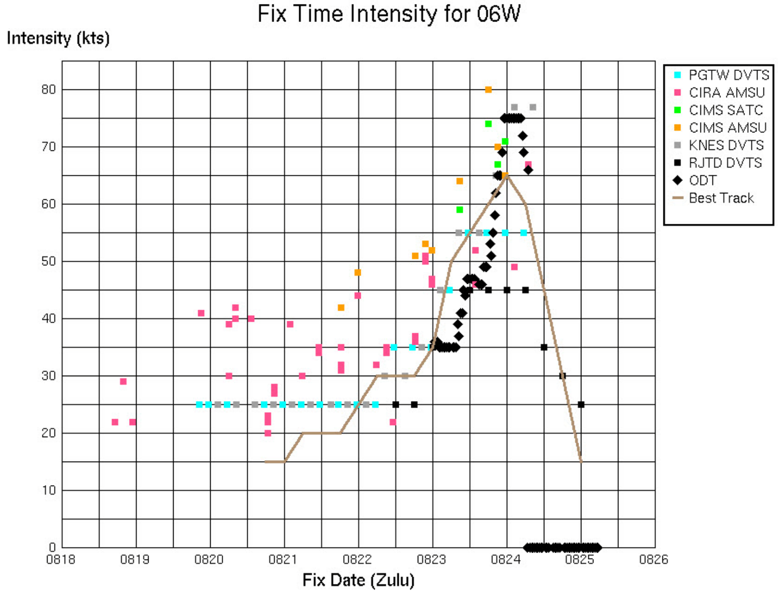


Typhoon 06W (Mindulle)

ISSUED POOR:	1400Z 19 Aug 2010
ISSUED FAIR:	2030Z 19 Aug 2010
FIRST TCFA:	1230Z 21 Aug 2010
FIRST WARNING:	0600Z 22 Aug 2010
LAST WARNING:	1200Z 24 Aug 2010
MAX INTENSITY:	65 Kts
NUMBER OF WARNINGS:	10

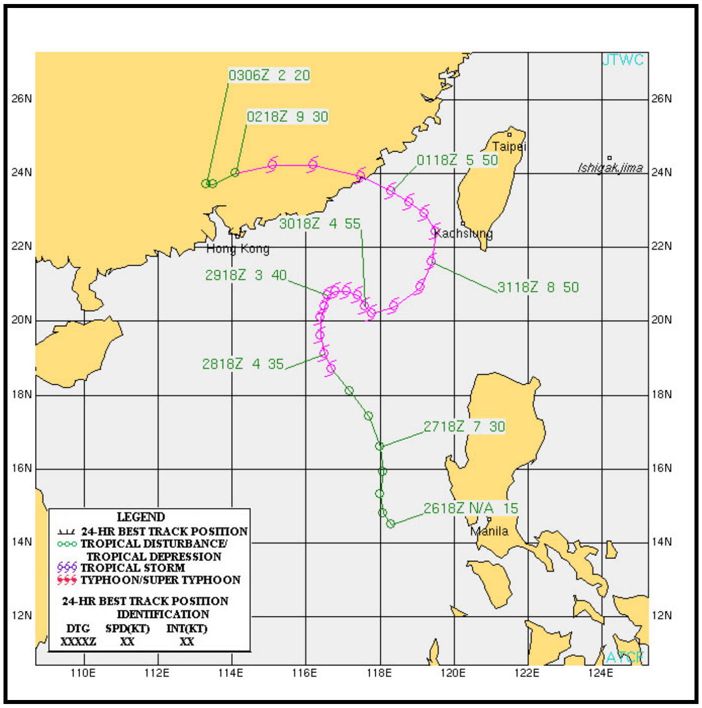


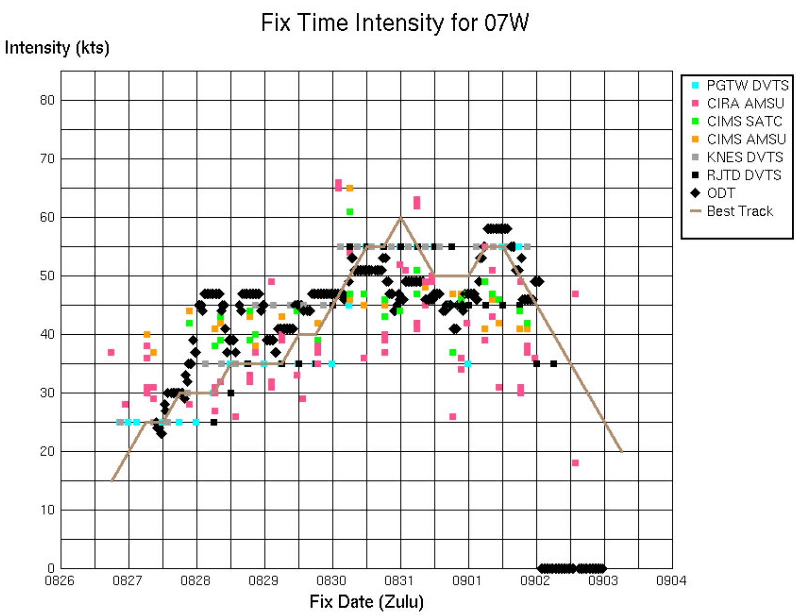
Fix Time Intensity for 06W



Tropical Storm 07W (Lionrock)

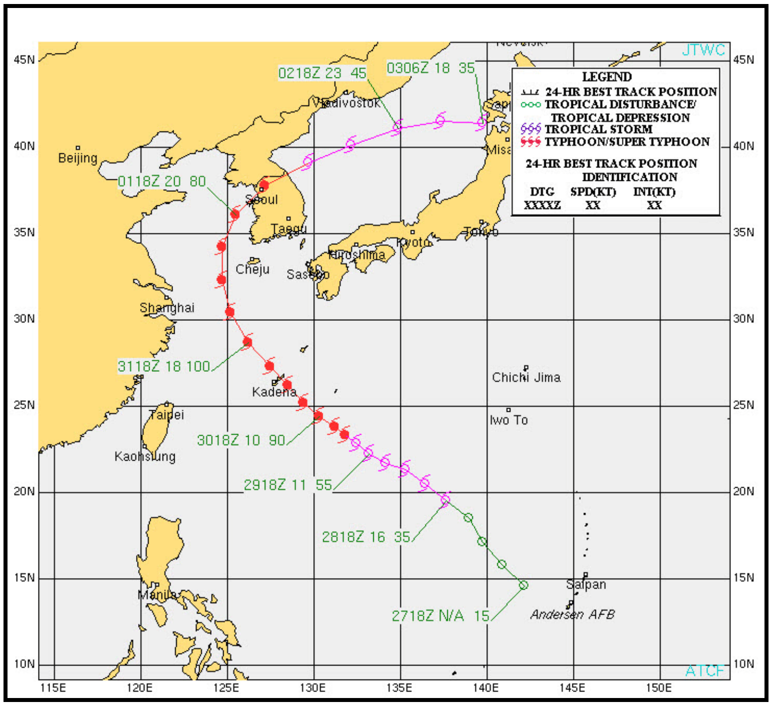
ISSUED POOR: 2300Z 26 Aug 2010
ISSUED FAIR: N/A
FIRST TCFA: 0430Z 27 Aug 2010
FIRST WARNING: 0600Z 27 Aug 2010
LAST WARNING: 0000Z 02 Sep 2010
MAX INTENSITY: 60 Kts
NUMBER OF WARNINGS: 24

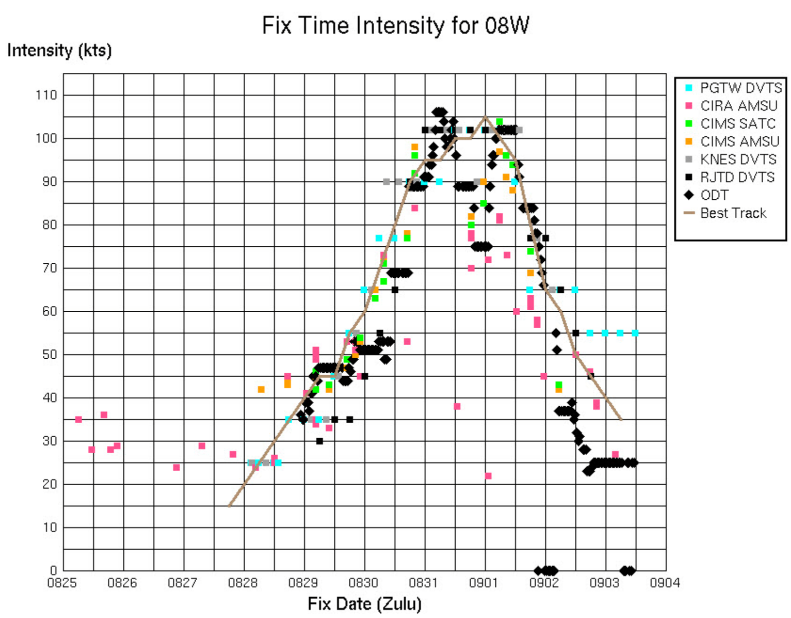




Typhoon 08W (Kompasu)

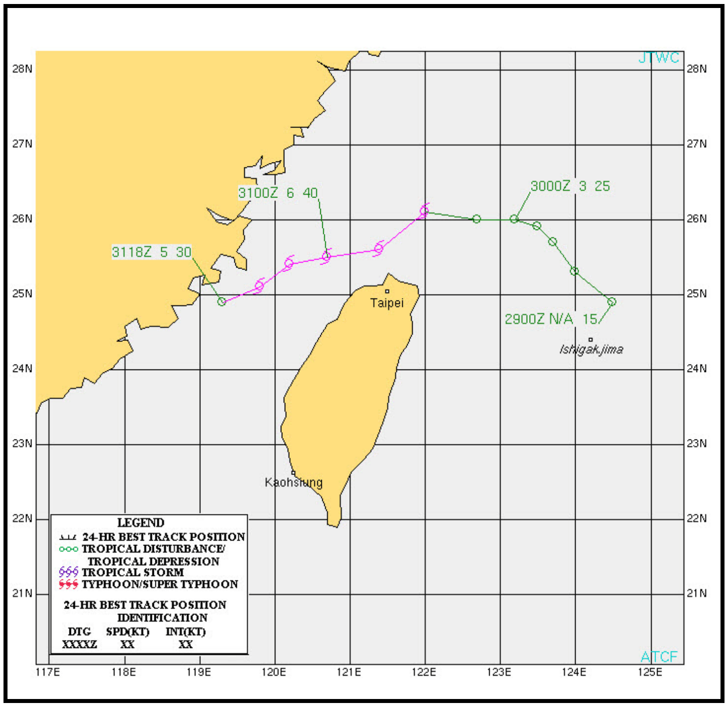
ISSUED POOR:	0600Z 28 Aug 2010
ISSUED FAIR:	1430Z 28 Aug 2010
FIRST TCFA:	1930Z 28 Aug 2010
FIRST WARNING:	2300Z 28 Aug 2010
LAST WARNING:	1200Z 02 Sep 2010
MAX INTENSITY:	105 Kts
NUMBER OF WARNINGS:	20

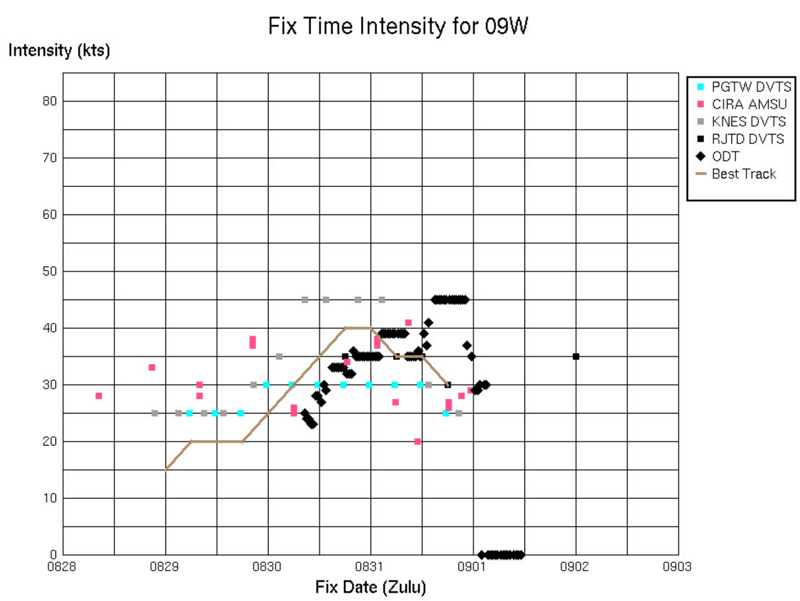




Tropical Storm 09W (Namtheun)

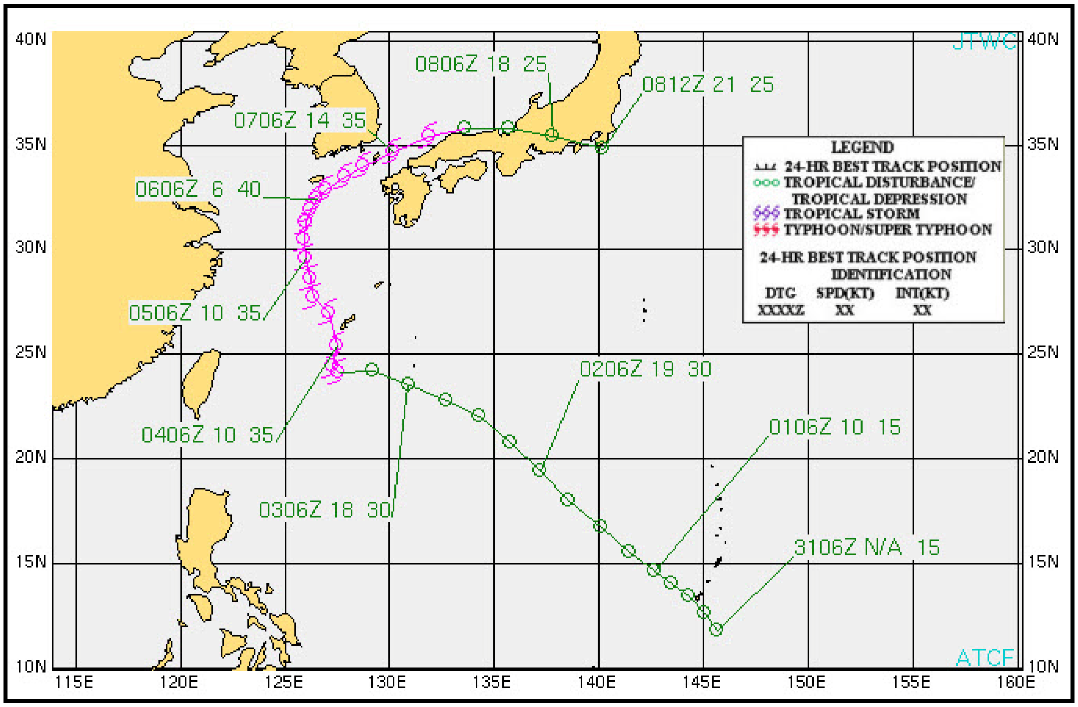
ISSUED POOR: 0130Z 29 Aug 2010
ISSUED FAIR: 0600Z 29 Aug 2010
FIRST TCFA: 0000Z 30 Aug 2010
FIRST WARNING: 0600Z 30 Aug 2010
LAST WARNING: 0300Z 01 Sep 2010
MAX INTENSITY: 40 Kts
NUMBER OF WARNINGS: 8

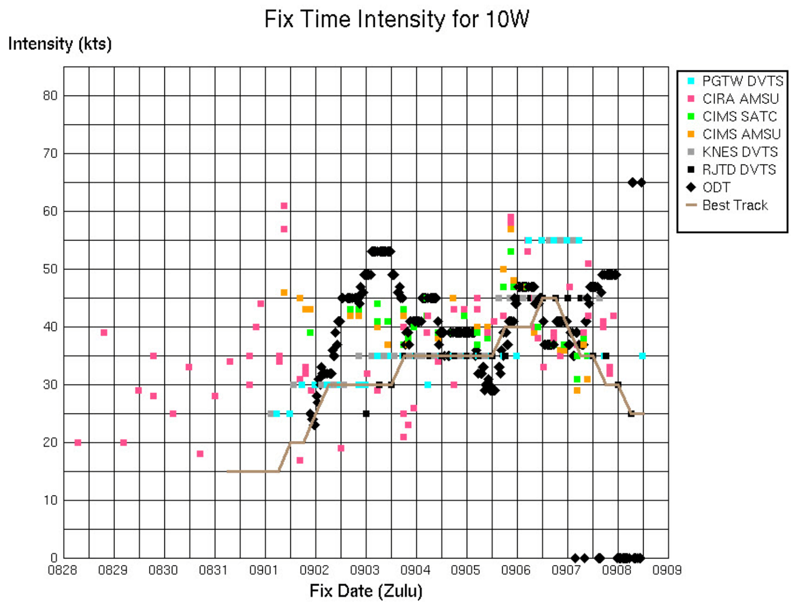




Tropical Storm 10W (Malou)

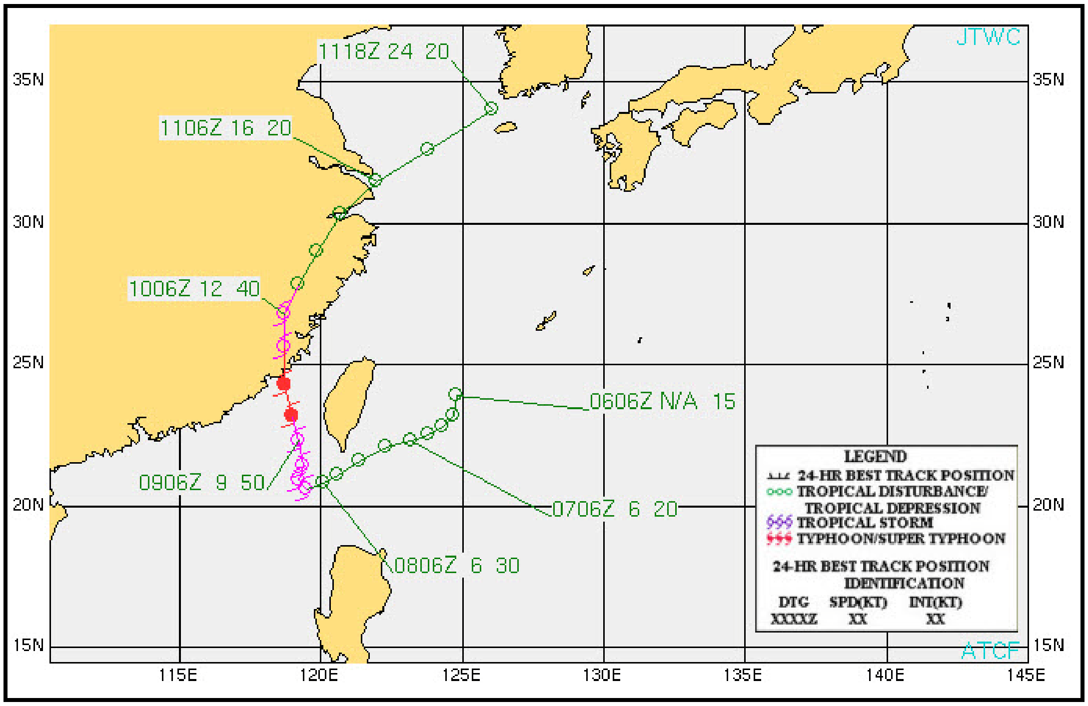
ISSUED POOR:	0600Z 30 Aug 2010
ISSUED FAIR:	0600Z 01 Sep 2010
FIRST TCFA:	1500Z 01 Sep 2010
FIRST WARNING:	1800Z 01 Sep 2010
LAST WARNING:	1200Z 07 Sep 2010
MAX INTENSITY:	45 Kts
NUMBER OF WARNINGS:	24

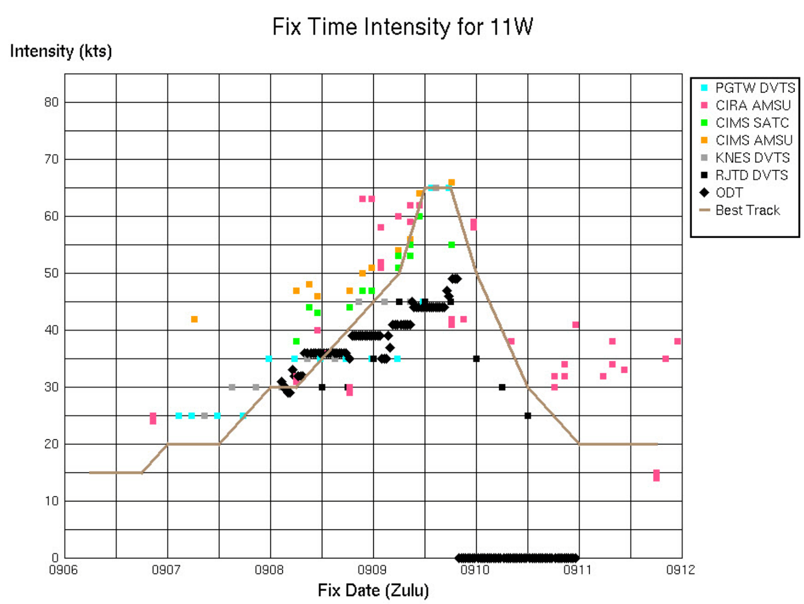




Typhoon 11W (Meranti)

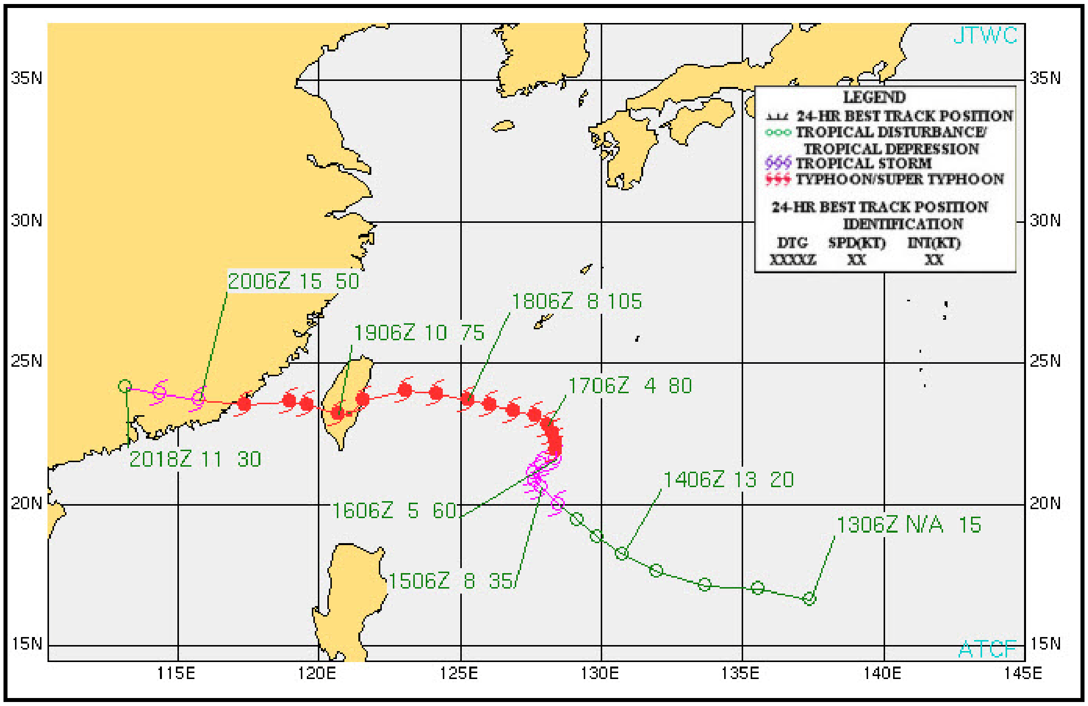
ISSUED POOR:	1030Z 07 Sep 2010
ISSUED FAIR:	1400Z 07 Sep 2010
FIRST TCFA:	2030Z 07 Sep 2010
FIRST WARNING:	0000Z 08 Sep 2010
LAST WARNING:	0000Z 10 Sep 2010
MAX INTENSITY:	65 Kts
NUMBER OF WARNINGS:	9

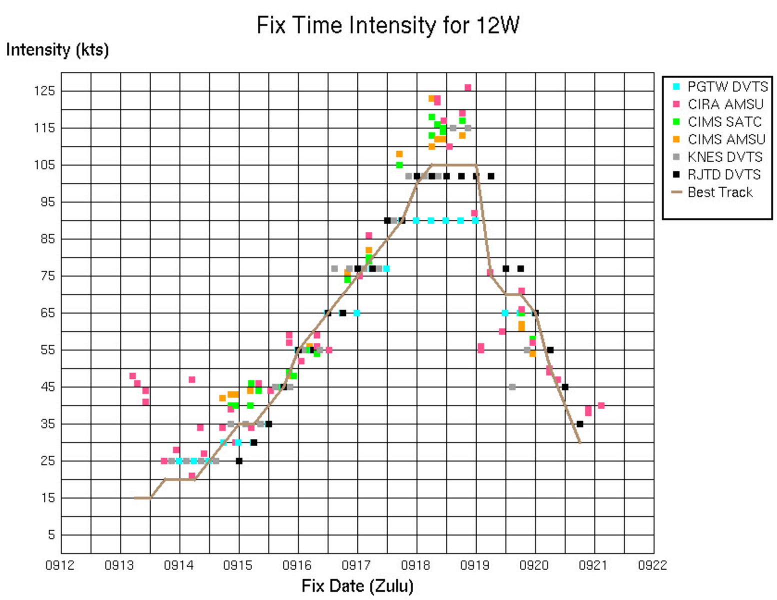




Typhoon 12W (Fanapi)

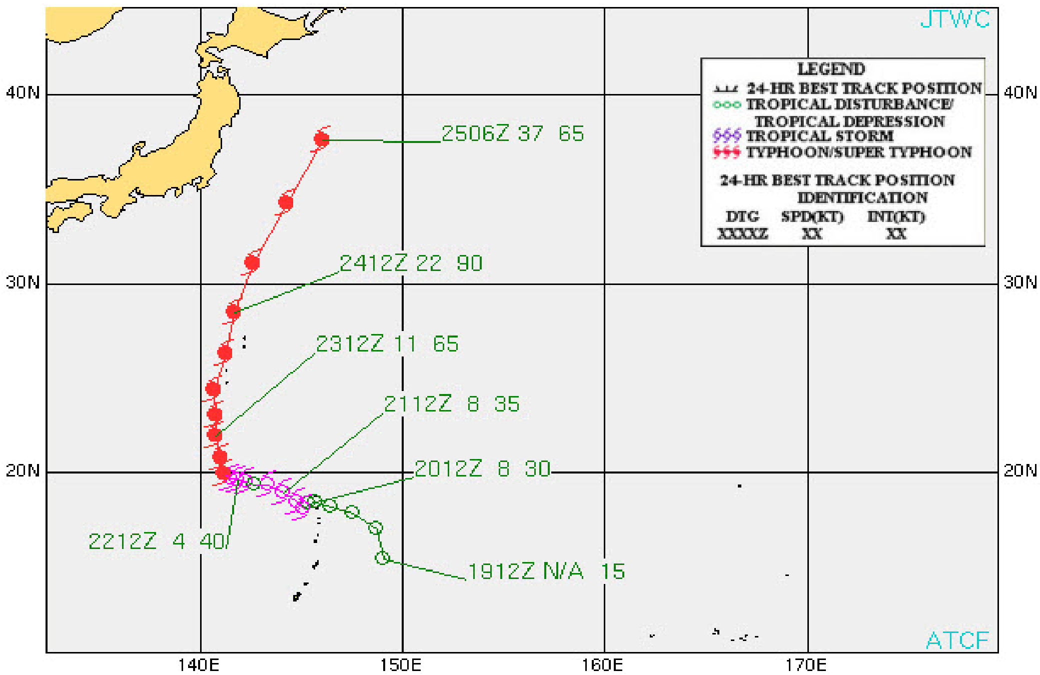
ISSUED POOR:	N/A
ISSUED FAIR:	1430Z 13 Sep 2010
FIRST TCFA:	0630Z 14 Sep 2010
FIRST WARNING:	1800Z 14 Sep 2010
LAST WARNING:	0600Z 20 Sep 2010
MAX INTENSITY:	105 Kts
NUMBER OF WARNINGS:	23

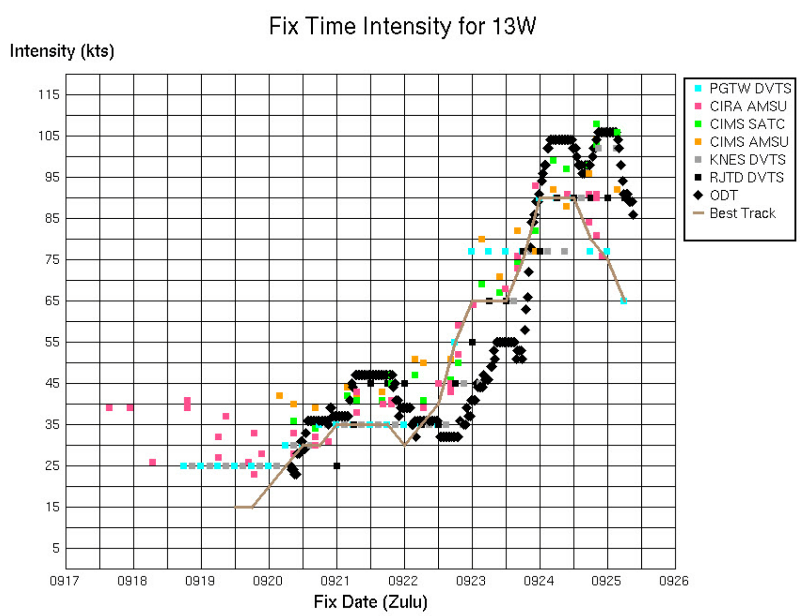




Typhoon 13W (Malakas)

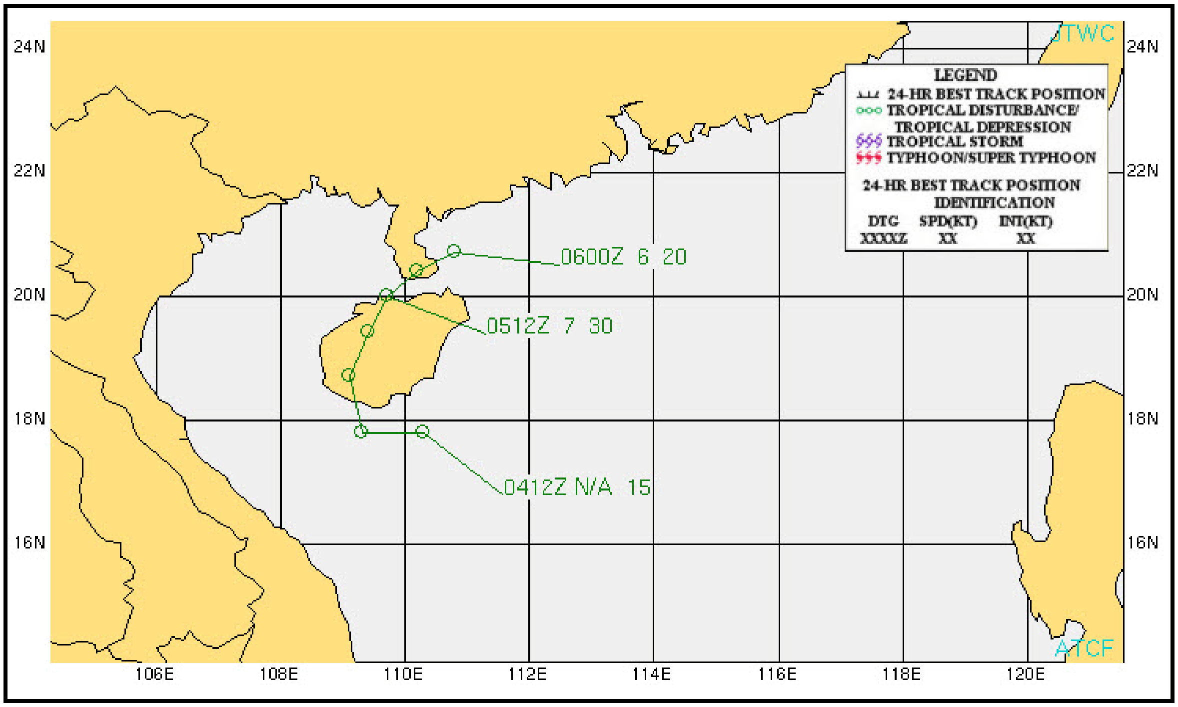
ISSUED POOR: N/A
ISSUED FAIR: 1800Z 18 Sep 2010
FIRST TCFA: 0300Z 19 Sep 2010
FIRST WARNING: 0600Z 20 Sep 2010
LAST WARNING: 0300Z 25 Sep 2010
MAX INTENSITY: 90 Kts
NUMBER OF WARNINGS: 20

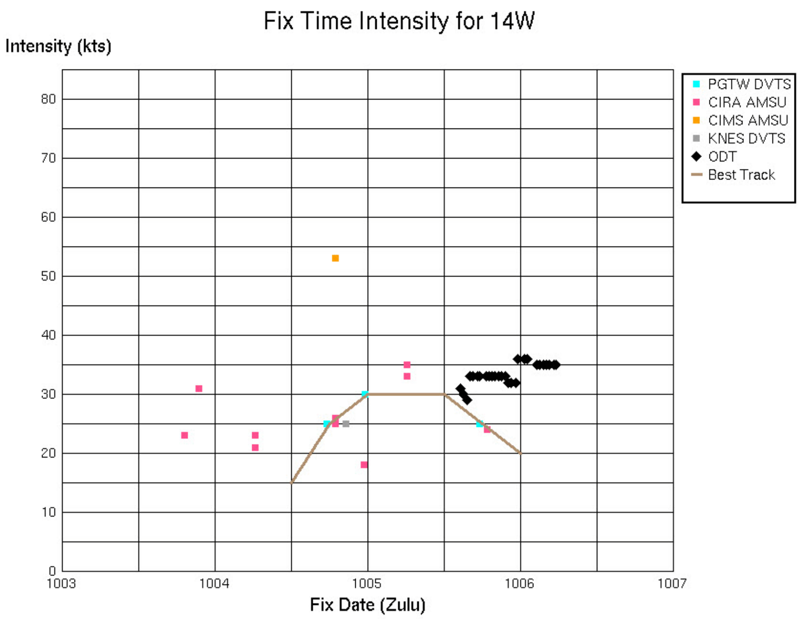




Tropical Depression 14W

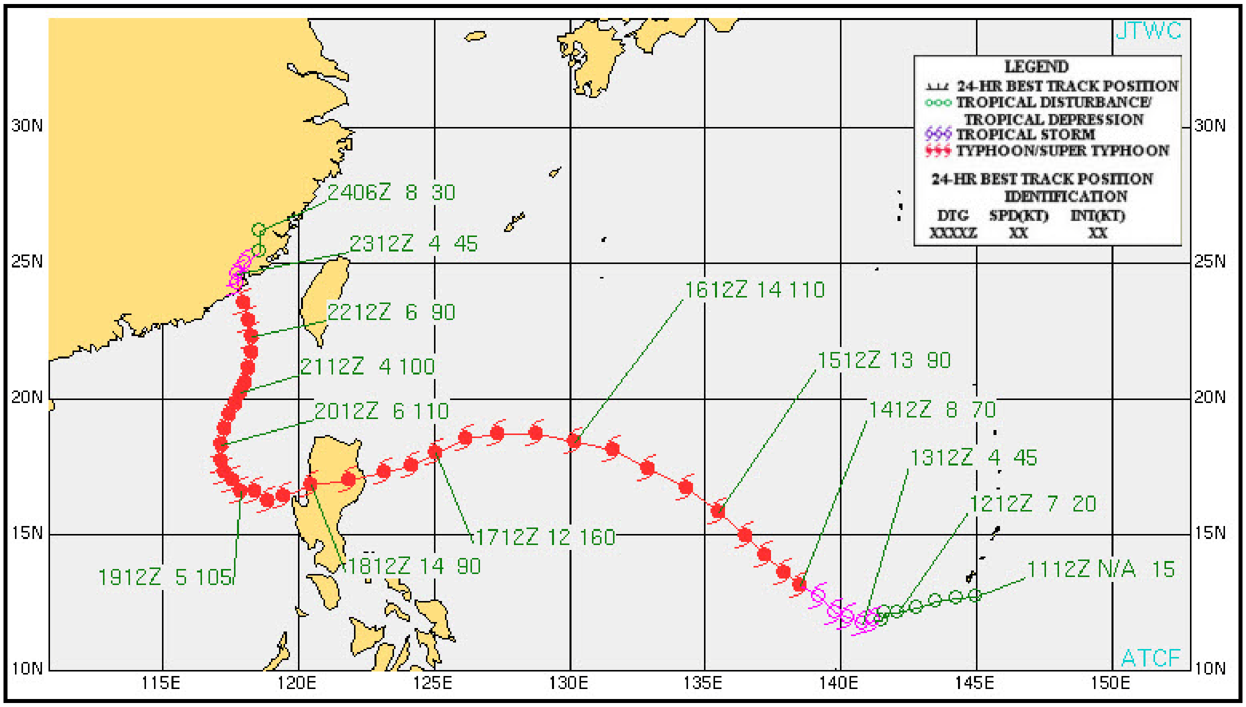
ISSUED POOR:	0600Z 04 Oct 2010
ISSUED FAIR:	1930Z 04 Oct 2010
FIRST TCFA:	2300Z 04 Oct 2010
FIRST WARNING:	0000Z 05 Oct 2010
LAST WARNING:	0000Z 06 Oct 2010
MAX INTENSITY:	30 Kts
NUMBER OF WARNINGS:	5

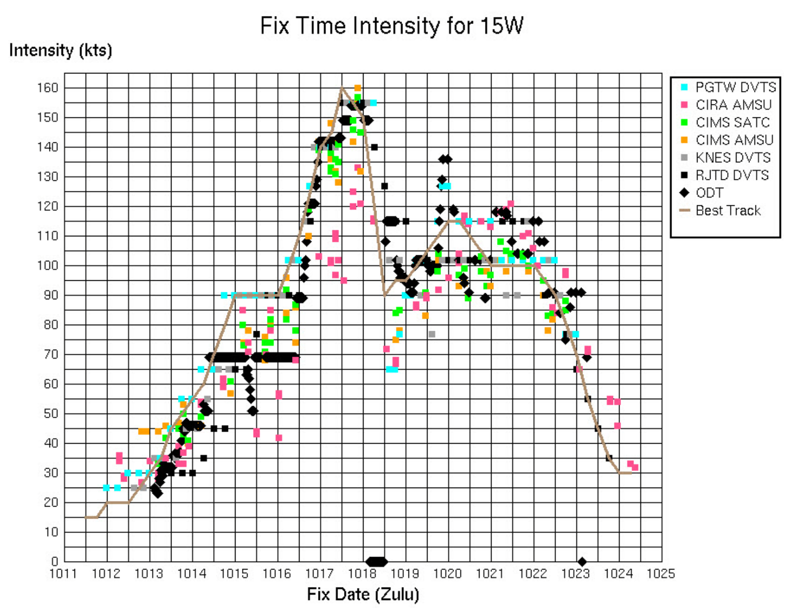




Super Typhoon 15W (Megi)

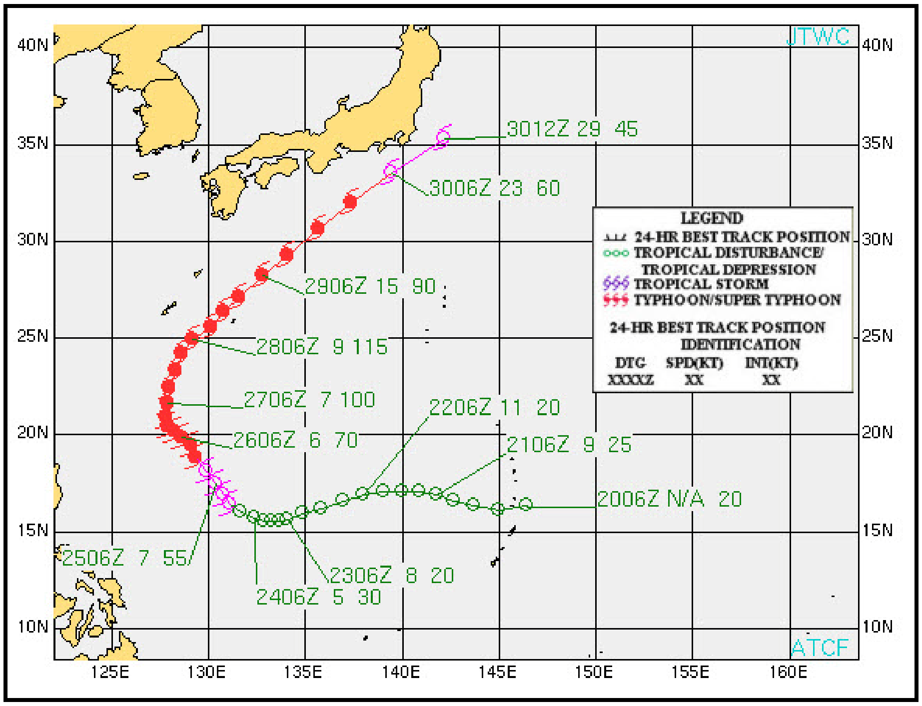
ISSUED POOR:	N/A
ISSUED FAIR:	0000Z 12 Oct 2010
FIRST TCFA:	0900Z 12 Oct 2010
FIRST WARNING:	0000Z 13 Oct 2010
LAST WARNING:	0600Z 23 Oct 2010
MAX INTENSITY:	160 Kts
NUMBER OF WARNINGS:	42

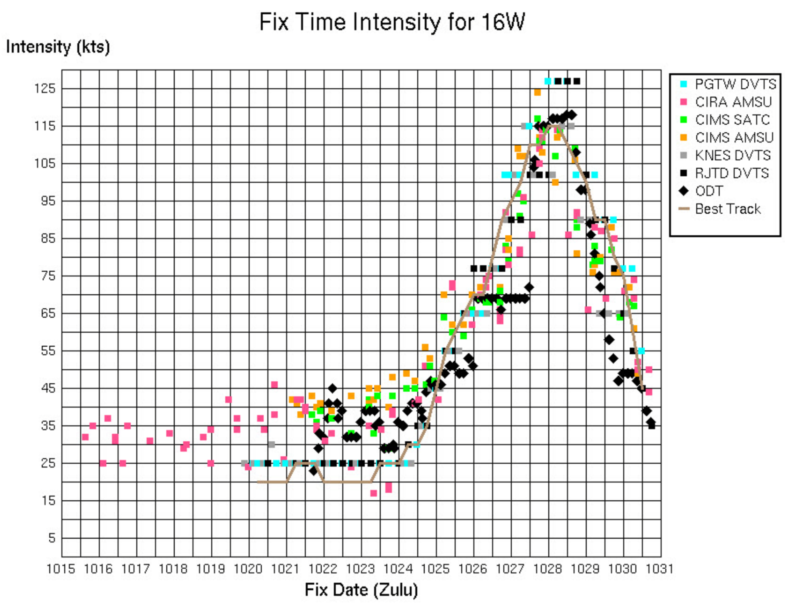




Typhoon 16W (Chaba)

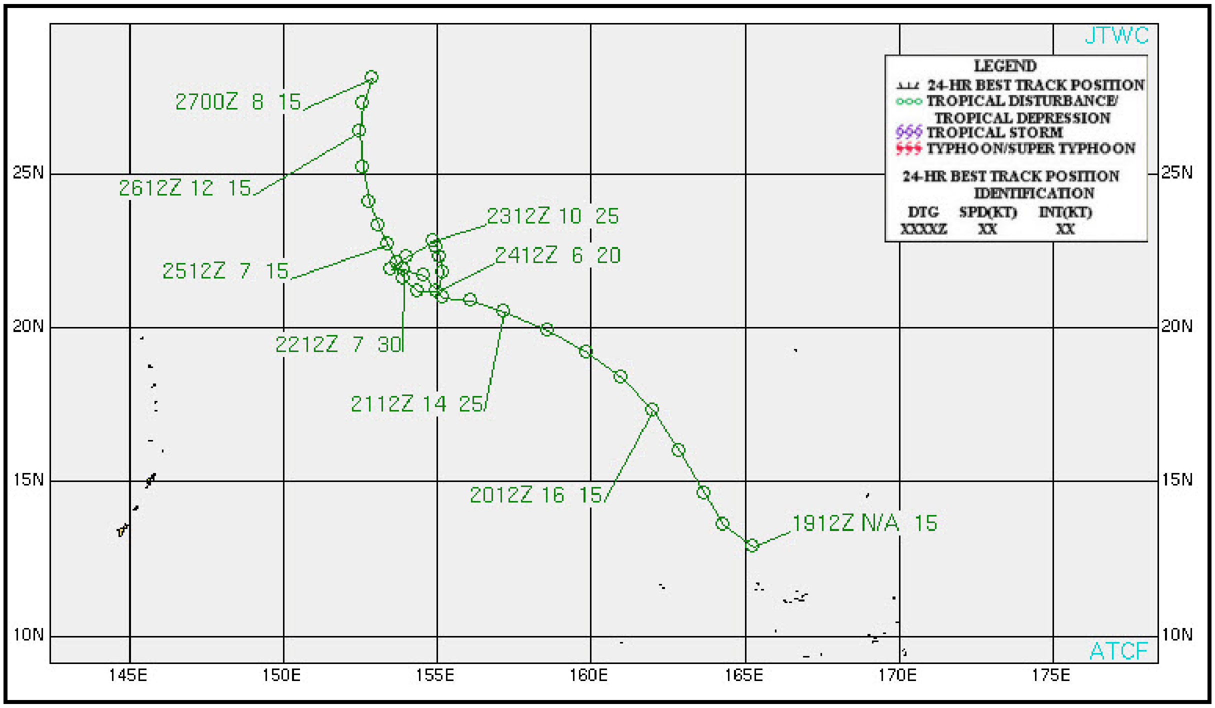
ISSUED POOR: 2000Z 19 Oct 2010
ISSUED FAIR: 0300Z 20 Oct 2010
FIRST TCFA: 0930Z 20 Oct 2010
FIRST WARNING: 1200Z 21 Oct 2010
LAST WARNING: 1200Z 30 Oct 2010
MAX INTENSITY: 115 Kts
NUMBER OF WARNINGS: 37

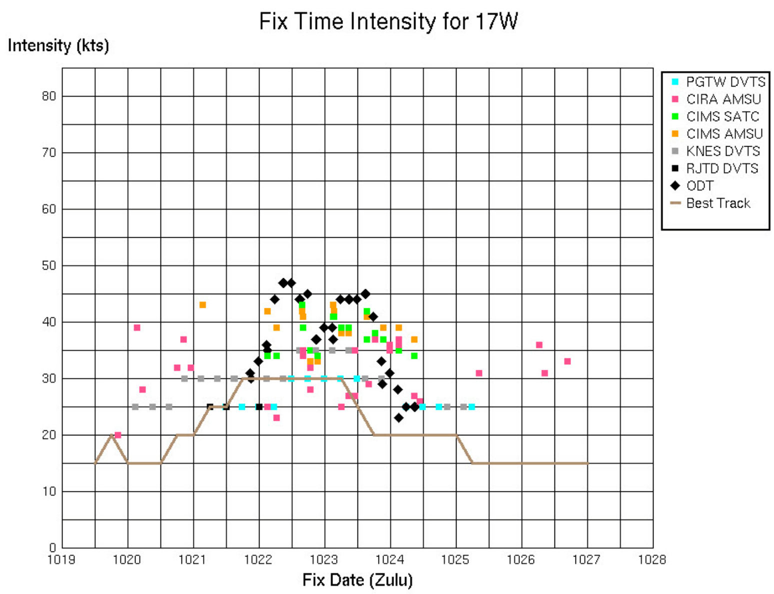




Tropical Depression 17W

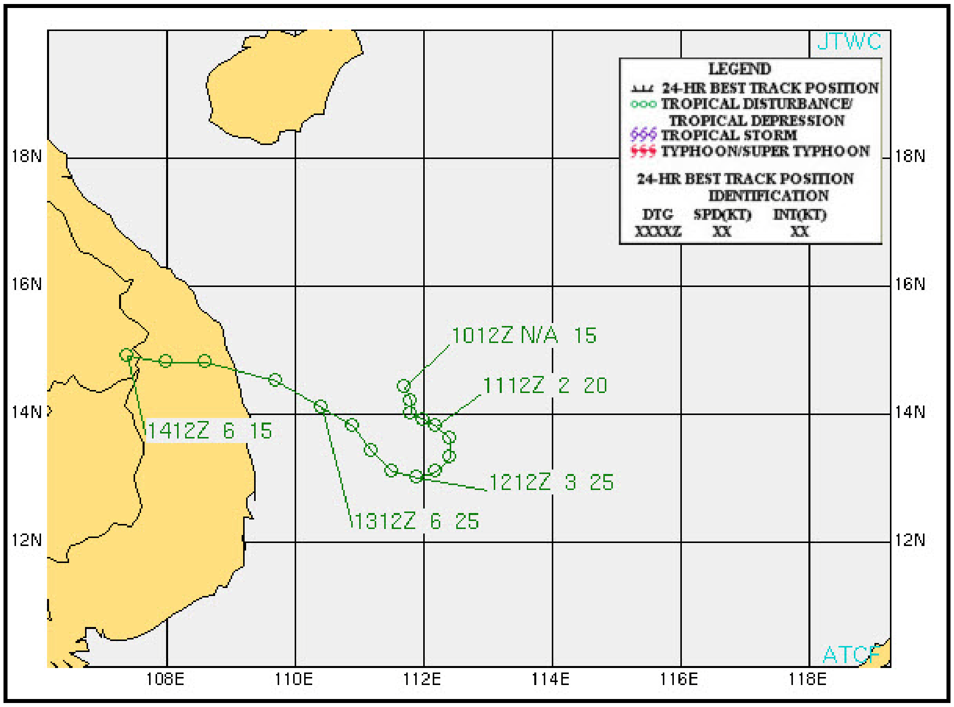
ISSUED POOR:	1930Z 20 Oct 2010
ISSUED FAIR:	2330Z 20 Oct 2010
FIRST TCFA:	0300Z 21 Oct 2010
FIRST WARNING:	1800Z 21 Oct 2010
LAST WARNING:	1200Z 23 Oct 2010
MAX INTENSITY:	30 Kts
NUMBER OF WARNINGS:	8

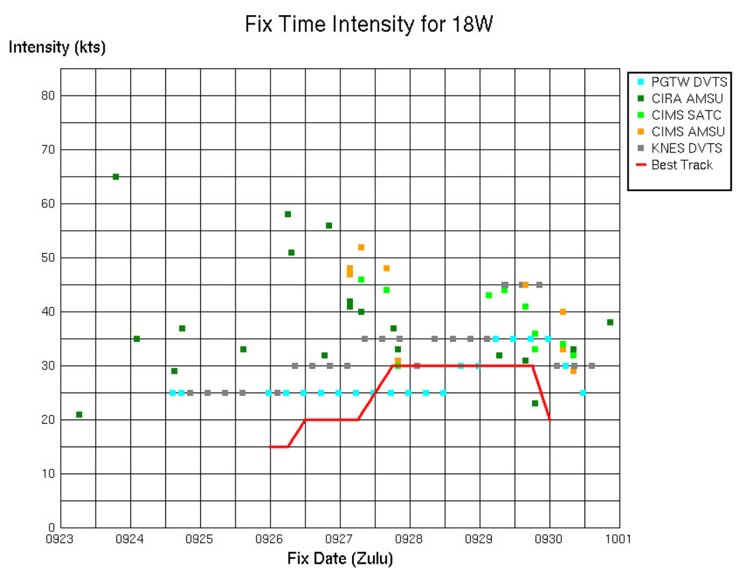




Tropical Depression 18W

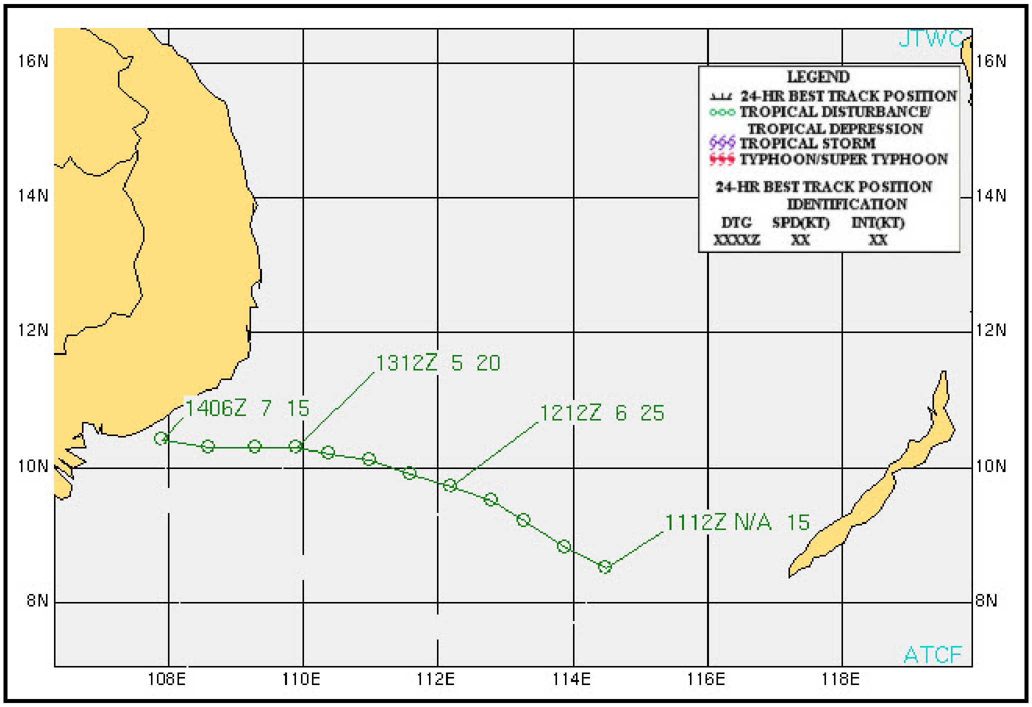
ISSUED POOR:	0900Z 11 Nov 2010
ISSUED FAIR:	1400Z 11 Nov 2010
FIRST TCFA:	2030Z 11 Nov 2010
FIRST WARNING:	1800Z 12 Nov 2010
LAST WARNING:	0300Z 14 Nov 2010
MAX INTENSITY:	25 Kts
NUMBER OF WARNINGS:	6

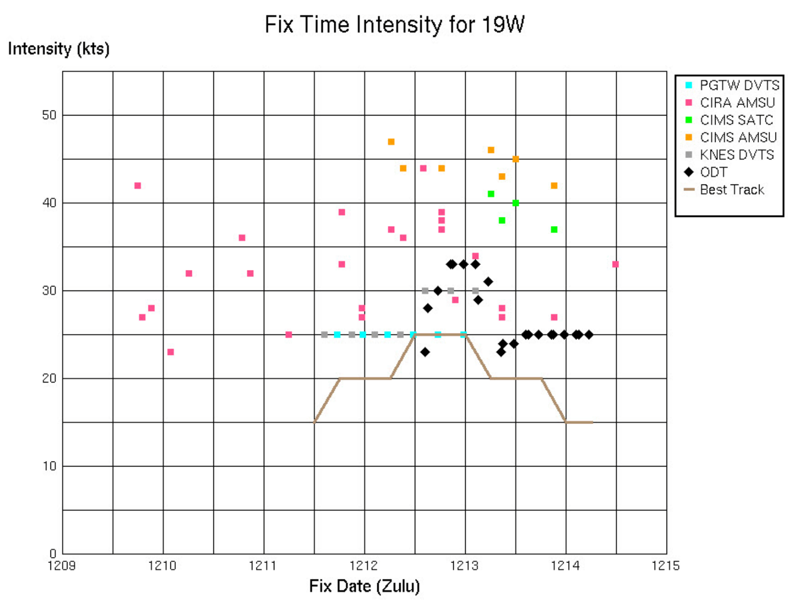




Tropical Depression 19W

ISSUED POOR:	2200Z 10 Dec 2010
ISSUED FAIR:	0600Z 11 Dec 2010
FIRST TCFA:	1930Z 11 Dec 2010
FIRST WARNING:	1200Z 12 Dec 2010
LAST WARNING:	0600Z 13 Dec 2010
MAX INTENSITY:	25 Kts
NUMBER OF WARNINGS:	4





Direct Cyclone Interaction between Tropical Storm (TS) 07W (Lionrock), Typhoon (TY) 08W (Kompasu) and Tropical Storm 09W (Namtheun)

The track and intensity changes noted with TS 07W and TS 09W indicate that direct cyclone interaction (DCI)[1] occurred between these cyclones. Review of the geostationary meteorological satellite data further indicates that the upper tropospheric outflow from TY 08W may have hindered the outflow from TS 09W and thus influenced the weakening of TS 09W.

Tropical Storm Lionrock (07W) developed west of Luzon on 26 August, intensified to a tropical depression on 27 August, while tracking slowly northward toward Taiwan. Typhoon Kompasu (08W) formed northwest of Guam on 27 August, tracked toward Okinawa along the southwestern periphery of a subtropical ridge, and rapidly intensified to typhoon strength on 30 August. Tropical Storm Namtheun (09W) formed on 29 August and strengthened to tropical storm by 30 August, just northeast of Taiwan, while tracking westward.

The first warning issued by JTWC on TS 09W (30 Aug/06Z), located this cyclone approximately 443 nautical miles (nm) northeast of TS 07W. Just prior to JTWC's first warning on TS 09W, TS 07W began to move more eastward toward the Luzon Strait. Subsequently both cyclones began to move cyclonically, suggestive of DCI; TS 07W moved eastward, southeastward, northeastward, northward, then northwestward and TS 09W moved westward then southwestward. After moving westward for approximately 24hrs, TS 07W moved inland and dissipated over China, whereas TS 09W dissipated earlier in the Taiwan Strait while on a southwestward heading (Figure 1-6).

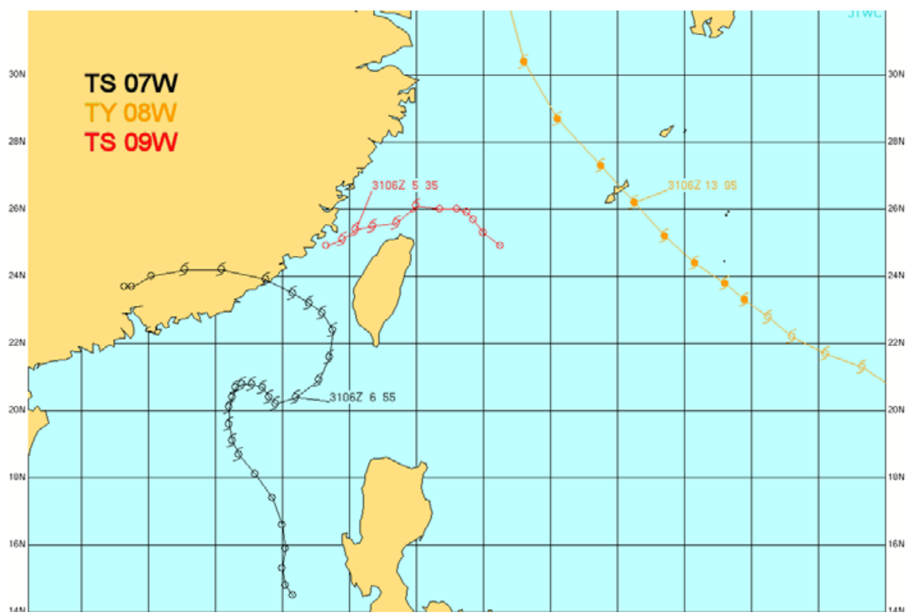


Figure 1-6. Six (6) hourly best track plots with 31 Aug 0600Z position, speed of movement, and intensity (knots) noted for comparison

Figure 1-7 shows the output from the ATCF "Fuji"[2] program for TS 07W and TS 09W. The Fuji program is a rudimentary routine run within ATCF, which is used to determine rotation around a centroid with information provided on separation distance, approach velocity and possible future

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[1] Terminology adopted from Carr, L. E. III, and R. L. Elsberry, 2000: Dynamical Tropical Cyclone Track Forecast Errors. Part I: Tropical Region Error Sources, *Mon. Wea. Rev.*, **15,** 641-661

[2] Acronym taken from the noted Fujiwhara effect; a term used to describe the rotation of two tropical cyclones around a common center.

movement. The output shown in figure 1-7 suggests that DCI occurred with the centroid of rotation located in the southern portion of the Taiwan Strait.

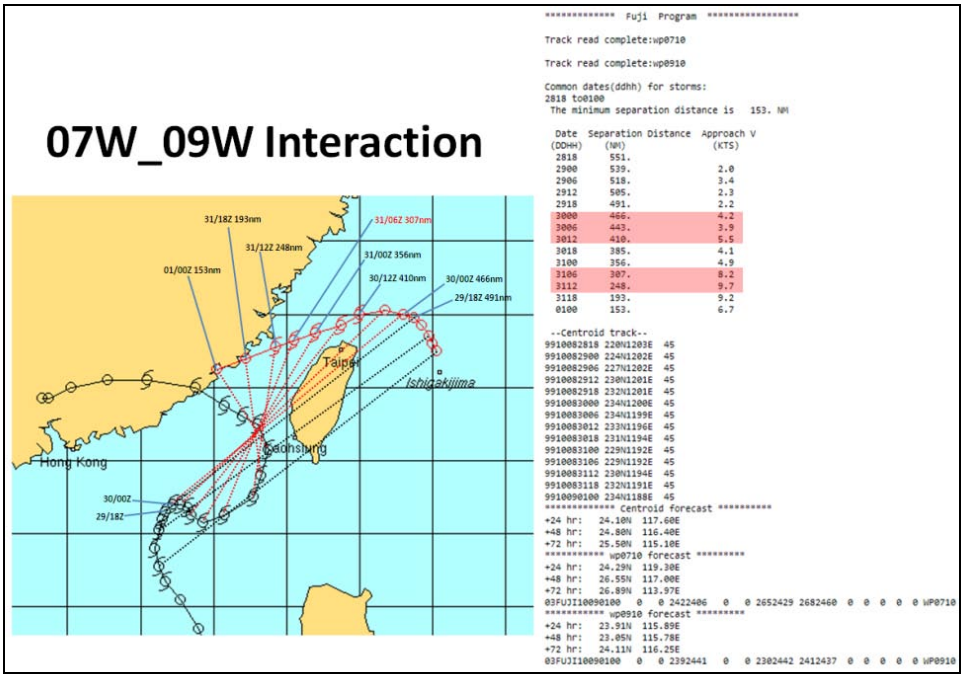

Figure 1-7. TS 07W and 09W best tracks, separation distances (left), and ATCF Fuji program output (right)

The early northward movement of TS 07W through the South China Sea, due to a weak lower to mid-tropospheric subtropical ridge over China, was noted as a period a large horizontal spread in numerical model forecast tracks (Figure 1-8 (29/12Z)). Subsequently, after the establishment and development of TS 09W, the numerical model track guidance, especially the ECMWF and JGSM models, began to decrease in horizontal spread and suggest possible DCI between the two cyclones (figure 1-8 (30/06Z and 30/18Z)).

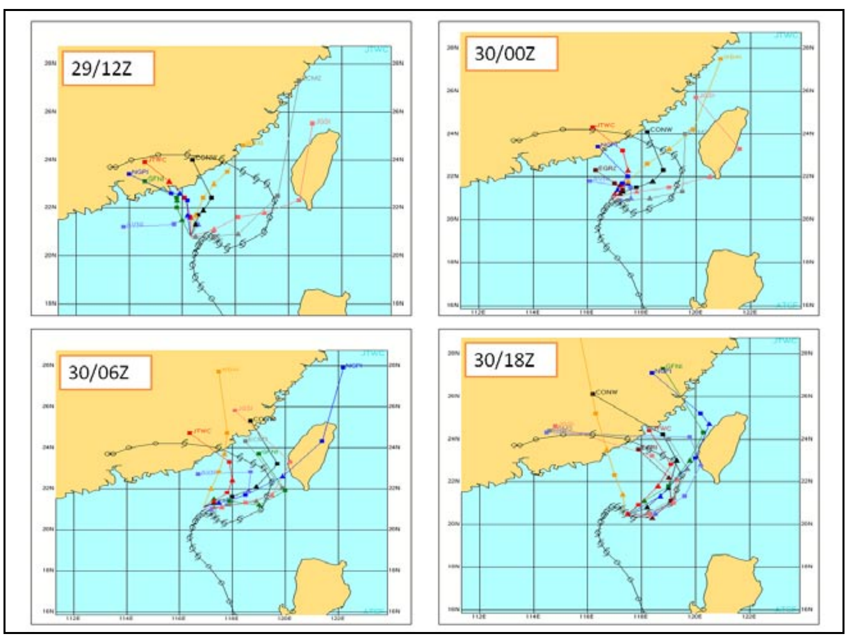

Figure 1-8. Numerical model guidance prior to and during the TS 07W and TS 09W DCI event

Review of the MTSAT IR3 (water vapor) data loops for the period of 30 Aug 0600Z to 01 Sep 0600Z indicates that during the interaction of TS 07W and 09W, the outflow from TY 08W may have also inhibited the outflow from TS 09W and aided weakening in the Taiwan Strait; allowing the weakening TS 09W to be “drawn” toward TS 07W.

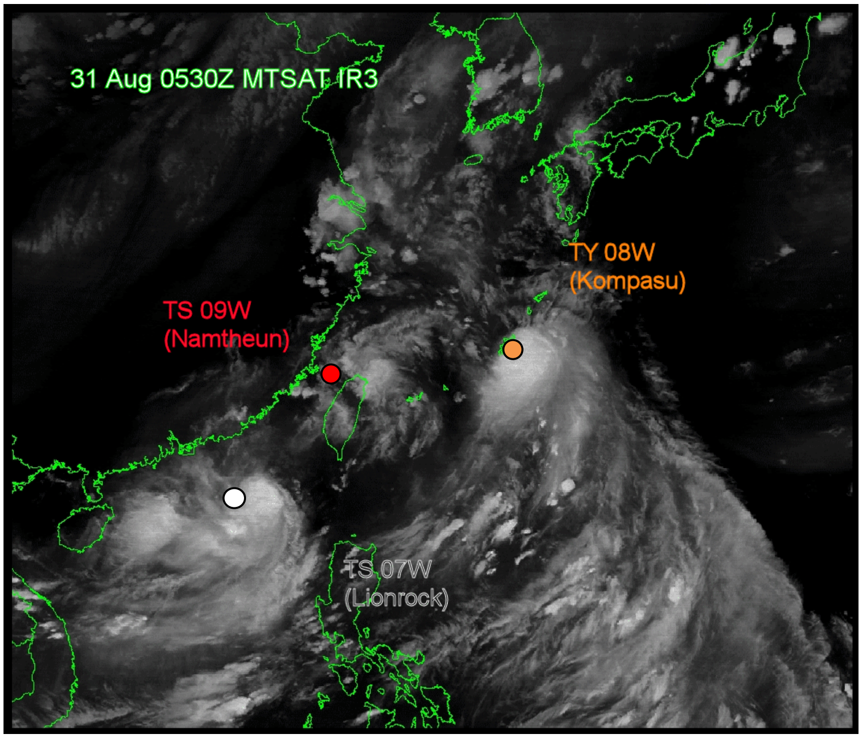

Figure 1-9. MTSAT IR3 (water vapor) image depicting TS 07W, TY 08W, and TS 09W. The colored dots indicate the relative positions at 31/0530Z: white for TS 07W, red for TS 09W, orange for TY 08W

The lack of robust tools to perform timely and accurate diagnoses of DCI events frustrated the JTWC attempt to provide support to DoD operations that were affected by these cyclones and remains a significant gap in JTWC’s forecast capability.

Tropical Storm (TS) 10W (Malou)

Tropical Storm (TS) 10W (Malou) is noted as a unique 2010 Northwest Pacific tropical cyclone due to the binary cyclone interaction (Carr 1997[1]) which occurred as this cyclone moved northwest toward Okinawa.

This cyclone developed northwest of Guam within the monsoon trough around 31 August and initially moved northwestward under the influence of a low- to mid-level subtropical ridge. Subsequently, a weaker cyclone to the southwest, developed and began to rotate cyclonically around the developing tropical storm. With the development of the second cyclone, TS 10W started to deflect to the left of the forecast track; between 02/1800Z – 03/1800Z September.

TS 10W then stalled southwest of Okinawa for several hours before making an abrupt turn to the north as the weaker circulation tracked northwestward along its eastern periphery. After the abrupt turn, Malou and the secondary circulation began to merge (see figure 1-10 for a microwave image mosaic of the two circulations).

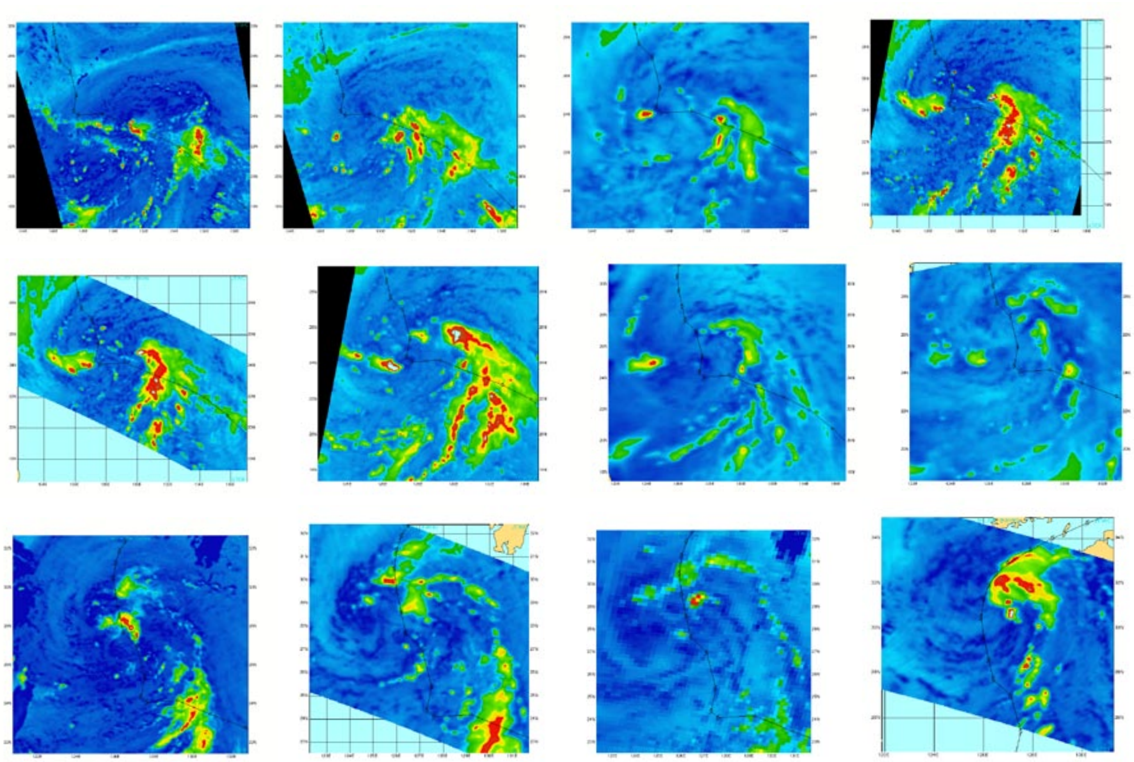

Figure 1-10. Microwave image mosaic showing rotation and eventual consolidation of two low level circulation centers.

During the early stages of TS 10W, JTWC failed to recognize the second, weaker circulation and consider its influence on the track and intensity of Malou. Forecasts issued between 02/1800Z and 03/1800Z predicted tropical cyclone passage over Okinawa (see figure 1-11) while the actual track deflected cyclonically with closest-point-of-approach to Okinawa occurring to the west of the island and later than forecast.

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[1] Carr, L. E. III, et al, *Observational Evidence for Alternate Modes of Track-Altering Binary Cyclone Scenarios*, **MWR** vol 125, issue 9, pp 2094-211, 1997

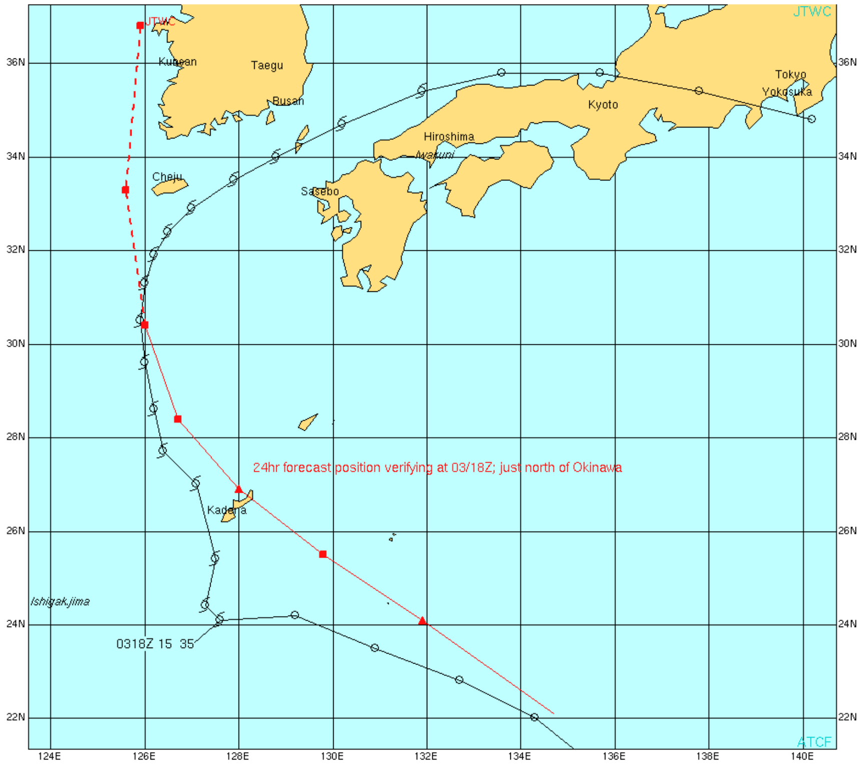


Figure 1-11. 02/18Z JTWC forecast in red, actual best track in black.

Following this cyclonic deflection, TS 10W slowed in forward motion and took a sharper turn to the north than was forecast by JTWC.

After the turn to the north, available numerical models forecasted another turn to the west (see figure 1-12), apparently in response (albeit late) to the influence from the second, weaker circulation. Also, during this period, TS 10W became more difficult to locate and appeared to be moving erratically based on the upper level cloud patterns and convective maxima. It was not until visible imagery became available, that the two low level cyclones were evident along the western side of the upper level circulation and maximum convection (see figure 1-13).

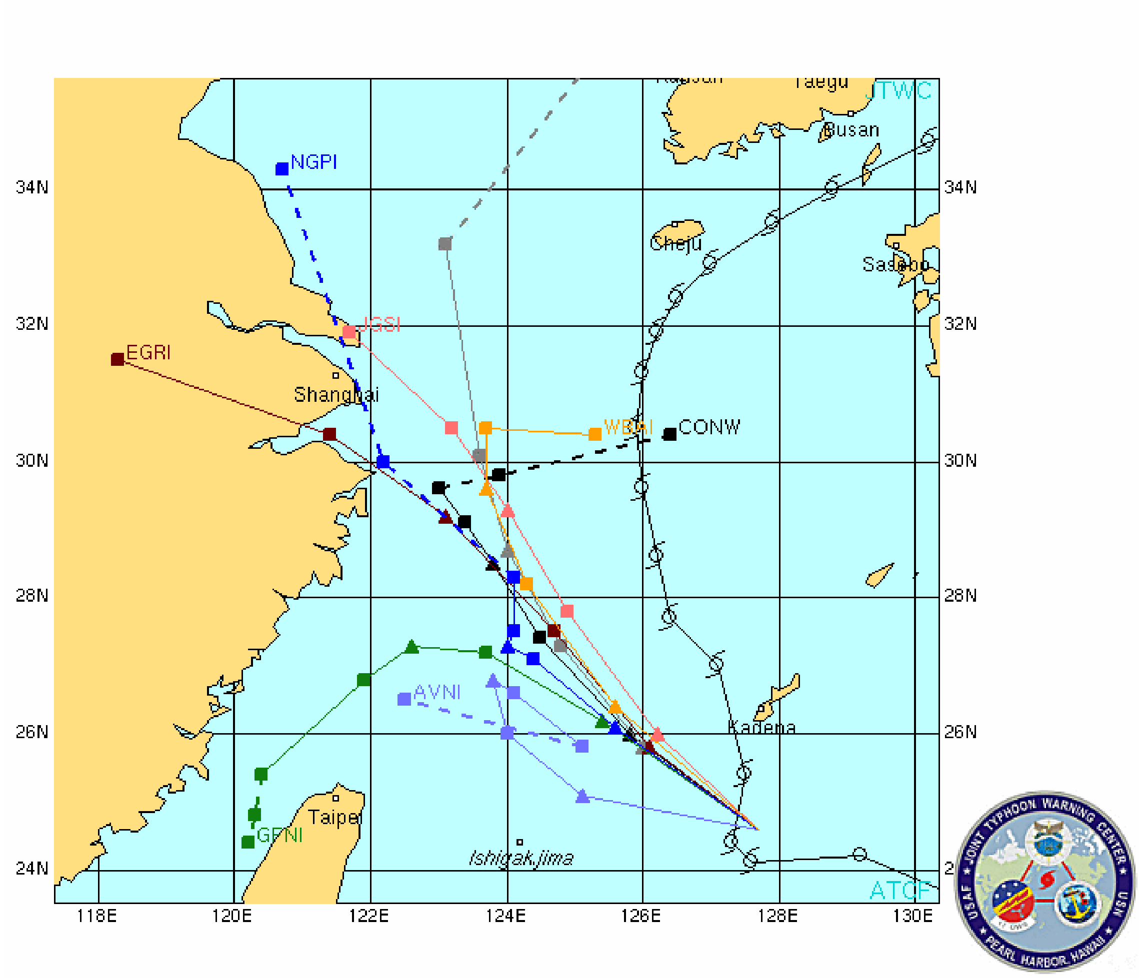


Figure 1-12. 03/18Z Objective aids forecasting deflection or movement westward when actual track turned to the North.

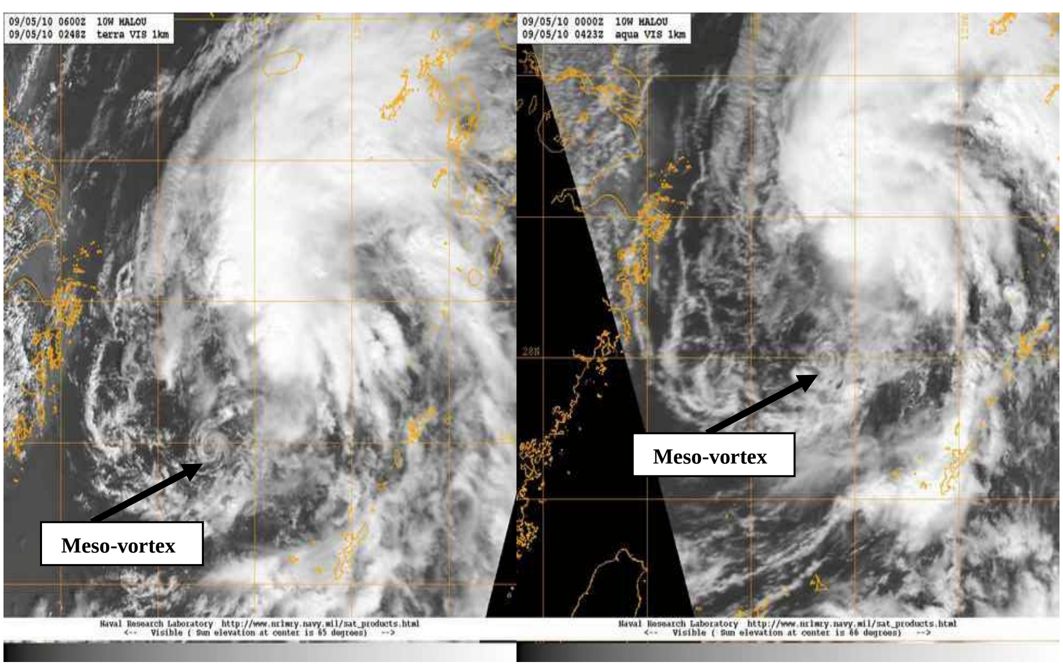


Figure 1-13 . Depicts meso-vorticies only identifiable in visible imagery rotating around the broad circulation cyclonically.

This mis-analyzed and lengthy binary interaction event also caused TS 10W to remain well below forecasted peak intensity. Peak intensities were expected to reach 85 knots, given that TS 10W was in an area where climatological data supported to at least typhoon intensity, however the

long period of binary interaction and subsequent inflow disruption caused by the second circulation appears to have stifled the development of TS 10W.

The mis-analysis of the second cyclone led JTWC to assess the system as elongated, which was incorrectly supported by scatterometry data which resolved or presented only one elongated circulation. This cyclone and past cyclone experiences indicate that the current scatterometry analysis algorithm quite often depicts only one circulation when numerous smaller vortices may be present.

As indicated in figure 1-10, microwave imagery suggests that binary interaction occurred, though it is not clear why this event was not detected by JTWC in the real-time. Review of the binary cyclone interaction between TY 29W (Pat) and TS 30W (Ruth) during the 1994 western Pacific typhoon season further supports the assessment that TS 10W Malou was part of a binary cyclone interaction event. Comparisons of the track of Malou and Pat show numerous similarities, despite the significant difference in interacting cyclone intensities of the two examples (figure 1-14).

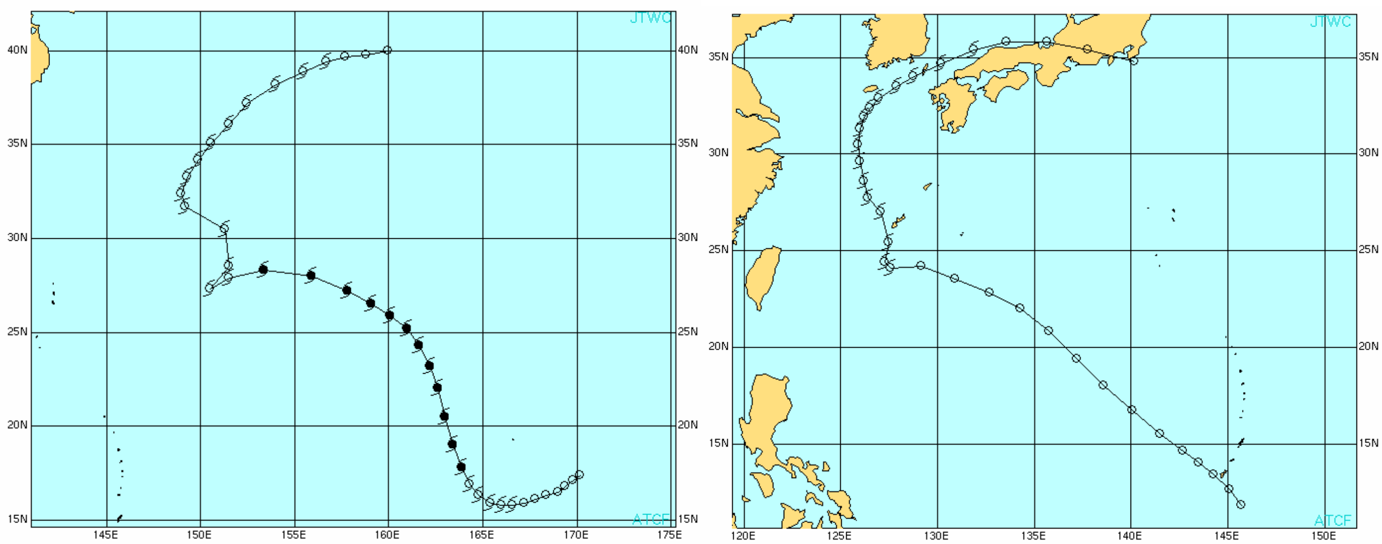


Figure 1-14. TY 29W (Pat), 1994, (left) and TS 10W (Malou), 2010, (right) show very similar cyclonic loops following abrupt track change. Pat was an intense cyclone that underwent binary cyclone interaction whereas Malou was much weaker.

Chapter 2 North Indian Ocean Tropical Cyclones

This chapter contains information on north Indian Ocean tropical cyclone activity during 2010 and the monthly distribution of Tropical Cyclone activity summarized for 1975 - 2010. North Indian Ocean tropical cyclone best tracks appear following Table 2-2.

Section 1 Informational Tables

Table 2-1 is a summary of Tropical Cyclone activity in the north Indian Ocean during the 2010 season. Five cyclones occurred in 2010, with three systems reaching intensity greater than 64 knots. Table 2-2 shows the monthly distribution of Tropical Cyclone activity for 1975 - 2010.

Table 2-1

NORTH INDIAN OCEAN SIGNIFICANT TROPICAL CYCLONES FOR 2010

(01 JAN 2010 - 31 DEC 2010)

TC	NAME*	PERIOD**	WARNINGS ISSUED	EST MAX SFC WINDS KTS	MSLP (MB)***
1B	Laila	17-21 May	17	65	974
2A	Bandu	19-22 May	14	55	982
3A	Phet	31 May- 06 Jun	24	125	929
4B	Giri	21-22 Oct	8	135	922
5B	Jal	4-7 Nov	12	45	989

* As designated by the responsible RSMC

** Dates are based on Issuance of JTWC warnings on system.

*** MSLP converted from estimated maximum surface winds using Knaff-Zehr wind-pressure relationship

Table 2 - 2

DISTRIBUTION OF NORTH INDIAN OCEAN TROPICAL CYCLONES

FOR 1975 - 2010

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
	1	0	0	0	2	0	0	0	0	1	2	0	6
1975	0 1 0	0 0 0	0 0 0	0 0 0	2 0 0	0 0 0	0 0 0	0 0 0	0 0 0	1 0 0	0 2 0	0 0 0	3 3 0
	0	0	0	1	0	1	0	0	1	1	0	1	5
1976	0 0 0	0 0 0	0 0 0	0 1 0	0 0 0	0 1 0	0 0 0	0 0 0	0 1 0	0 1 0	0 0 0	0 1 0	0 5 0
	0	0	0	0	1	1	0	0	0	1	0	2	5
1977	0 0 0	0 0 0	0 0 0	0 0 0	0 1 0	0 1 0	0 0 0	0 0 0	0 0 0	0 1 0	0 0 0	1 1 0	1 4 0
	0	0	0	0	1	0	0	0	0	1	2	0	4
1978	0 0 0	0 0 0	0 0 0	0 0 0	0 1 0	0 0 0	0 0 0	0 0 0	0 0 0	0 1 0	2 0 0	0 0 0	2 2 0
	0	0	0	0	1	1	0	0	2	1	2	0	7
1979	0 0 0	0 0 0	0 0 0	0 0 0	1 0 0	0 1 0	0 0 0	0 0 0	0 1 1	0 1 0	0 1 1	0 0 0	1 4 2
	0	0	0	0	0	0	0	0	0	0	1	1	2
1980	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 1 0	0 1 0	0 2 0
	0	0	0	0	0	0	0	0	1	0	1	1	3
1981	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 1 0	0 0 0	1 0 0	1 0 0	2 1 0
	0	0	0	0	1	1	0	0	0	2	1	0	5
1982	0 0 0	0 0 0	0 0 0	0 0 0	1 0 0	0 1 0	0 0 0	0 0 0	0 0 0	0 2 0	1 0 0	0 0 0	2 3 0
	0	0	0	0	0	0	0	1	0	1	1	0	3
1983	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 1 0	0 0 0	0 1 0	0 1 0	0 0 0	0 3 0
	0	0	0	0	1	0	0	0	0	1	2	0	4
1984	0 0 0	0 0 0	0 0 0	0 0 0	0 1 0	0 0 0	0 0 0	0 0 0	0 0 0	0 1 0	2 0 0	0 0 0	2 2 0
	0	0	0	0	2	0	0	0	0	2	1	1	6
1985	0 0 0	0 0 0	0 0 0	0 0 0	0 2 0	0 0 0	0 0 0	0 0 0	0 0 0	0 2 0	0 1 0	0 1 0	0 6 0
	1	0	0	0	0	0	0	0	0	0	2	0	3
1986	0 1 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 2 0	0 0 0	0 3 0
	0	1	0	0	0	2	0	0	0	2	1	2	8
1987	0 0 0	0 1 0	0 0 0	0 0 0	0 0 0	0 2 0	0 0 0	0 0 0	0 0 0	0 2 0	0 1 0	0 2 0	0 8 0
	0	0	0	0	0	1	0	0	0	1	2	1	5
1988	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 1 0	0 0 0	0 0 0	0 0 0	0 1 0	1 1 0	0 1 0	1 4 0
	0	0	0	0	1	1	0	0	0	0	1	0	3
1989	0 0 0	0 0 0	0 0 0	0 0 0	0 1 0	0 1 0	0 0 0	0 0 0	0 0 0	0 0 0	1 0 0	0 0 0	1 2 0
	0	0	0	1	1	0	0	0	0	0	1	1	4
1990	0 0 0	0 0 0	0 0 0	0 0 1	1 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 1	0 1 0	1 1 2
	1	0	0	1	0	1	0	0	0	0	1	0	4
1991	0 1 0	0 0 0	0 0 0	1 0 0	0 0 0	0 1 0	0 0 0	0 0 0	0 0 0	0 0 0	1 0 0	0 0 0	2 2 0
	0	0	0	0	1	2	1	0	1	3	3	2	13
1992	0 0 0	0 0 0	0 0 0	0 0 0	1 0 0	0 2 0	0 1 0	0 0 0	0 0 1	0 2 1	2 1 0	0 2 0	3 8 2
	0	0	0	0	0	0	0	0	0	0	2	0	2
1993	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	2 0 0	0 0 0	2 0 0
	0	0	1	1	0	1	0	0	0	1	1	0	5
1994	0 0 0	0 0 0	0 1 0	1 0 0	0 0 0	0 1 0	0 0 0	0 0 0	0 0 0	0 1 0	0 1 0	0 0 0	1 4 0
	0	0	0	0	0	0	0	0	1	1	2	0	4
1995	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 1 0	0 1 0	2 0 0	0 0 0	2 2 0

	0	0	0	0	1	3	0	0	0	2	2	0	8
1996	0 0 0	0 0 0	0 0 0	0 0 0	0 1 0	1 2 0	0 0 0	0 0 0	0 0 0	1 1 0	2 0 0	0 0 0	4 4 0
	0	0	0	0	1	0	0	0	1	1	1	0	4
1997	0 0 0	0 0 0	0 0 0	0 0 0	1 0 0	0 0 0	0 0 0	0 0 0	1 0 0	0 1 0	0 1 0	0 0 0	2 2 0
	0	0	0	0	2	1	0	0	1	1	2	1	8
1998	0 0 0	0 0 0	0 0 0	0 0 0	1 1 0	1 0 0	0 0 0	0 0 0	0 1 0	0 1 0	2 0 0	1 0 0	5 3 0
	0	1	0	0	1	1	0	0	0	2	0	0	5
1999	0 0 0	0 1 0	0 0 0	0 0 0	1 0 0	0 1 0	0 0 0	0 0 0	0 0 0	2 0 0	0 0 0	0 0 0	3 2 0
	0	0	0	0	0	0	0	0	0	2	1	1	4
2000	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 2 0	1 0 0	0 1 0	1 3 0
	0	0	0	0	1	0	0	0	1	1	1	0	4
2001	0 0 0	0 0 0	0 0 0	0 0 0	1 0 0	0 0 0	0 0 0	0 0 0	0 1 0	0 1 0	0 0 1	0 0 0	1 2 1
	0	0	0	0	2	0	0	0	0	0	2	1	5
2002	0 0 0	0 0 0	0 0 0	0 0 0	0 2 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 2 0	0 1 0	0 5 0
	0	0	0	0	1	0	0	0	0	0	1	1	3
2003	0 0 0	0 0 0	0 0 0	0 0 0	1 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	1 0 0	0 1 0	2 1 0
	0	0	0	0	2	0	0	0	0	2	1	0	5
2004	0 0 0	0 0 0	0 0 0	0 0 0	0 2 0	0 0 0	0 0 0	0 0 0	0 0 0	0 2 0	1 0 0	0 0 0	1 4 0
	2	0	0	0	0	0	0	0	0	2	1	2	7
2005	0 1 1	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 2 0	0 1 0	0 2 0	0 6 1
	1	0	0	1	0	0	1	0	2	0	1	0	6
2006	0 1 0	0 0 0	0 0 0	1 0 0	0 0 0	0 0 0	0 1 0	0 0 0	0 2 0	0 0 0	0 1 0	0 0 0	1 5 0
	0	0	0	0	1	3	0	0	0	1	1	0	6
2007	0 0 0	0 0 0	0 0 0	0 0 0	1 0 0	1 2 0	0 0 0	0 0 0	0 0 0	0 1 0	1 0 0	0 0 0	3 3 0
	0	0	0	1	0	0	0	0	1	2	2	1	7
2008	0 0 0	0 0 0	0 0 0	1 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 1 0	0 1 1	0 2 0	0 1 0	1 5 1
	0	0	0	1	1	0	0	0	1	0	1	1	5
2009	0 0 0	0 0 0	0 0 0	0 1 0	1 0 0	0 0 0	0 0 0	0 0 0	0 1 0	0 0 0	0 1 0	0 1 0	1 4 0
	0	0	0	0	2	1	0	0	0	1	1	0	5
2010	0 0 0	0 0 0	0 0 0	0 0 0	1 1 0	1 0 0	0 0 0	0 0 0	0 0 0	1 0 0	0 1 0	0 0 0	3 2 0
(1975-2010)													
MEAN	0.2	0.1	0.0	0.2	0.7	0.6	0.1	0.0	0.3	0.9	1.2	0.5	4.8
CASES	6	2	1	7	27	21	2	1	13	36	47	20	183

The criteria used in TABLE 1-6 are as follows:

1) If a tropical cyclone was first warned on during the last two days of a particular month and continued into the next month for longer than two days, then that system was attributed to the second month.

2) If a tropical cyclone was warned on prior to the last two days of a month, it was attributed to the first month, regardless of how long the system lasted.

3) If a tropical cyclone began on the last day of the month and ended on the first day of the next month, that system was attributed to the first month. However, if a tropical cyclone began on the last day of the month and continued into the next month for only two days, then it was attributed to the second month.

TABLE 2-2 Legend		
Total month/year		
GTE 64 knots (Typhoon)	34 to 63 knots (Tropical Storm)	LTE 33 knots (Tropical Depression)

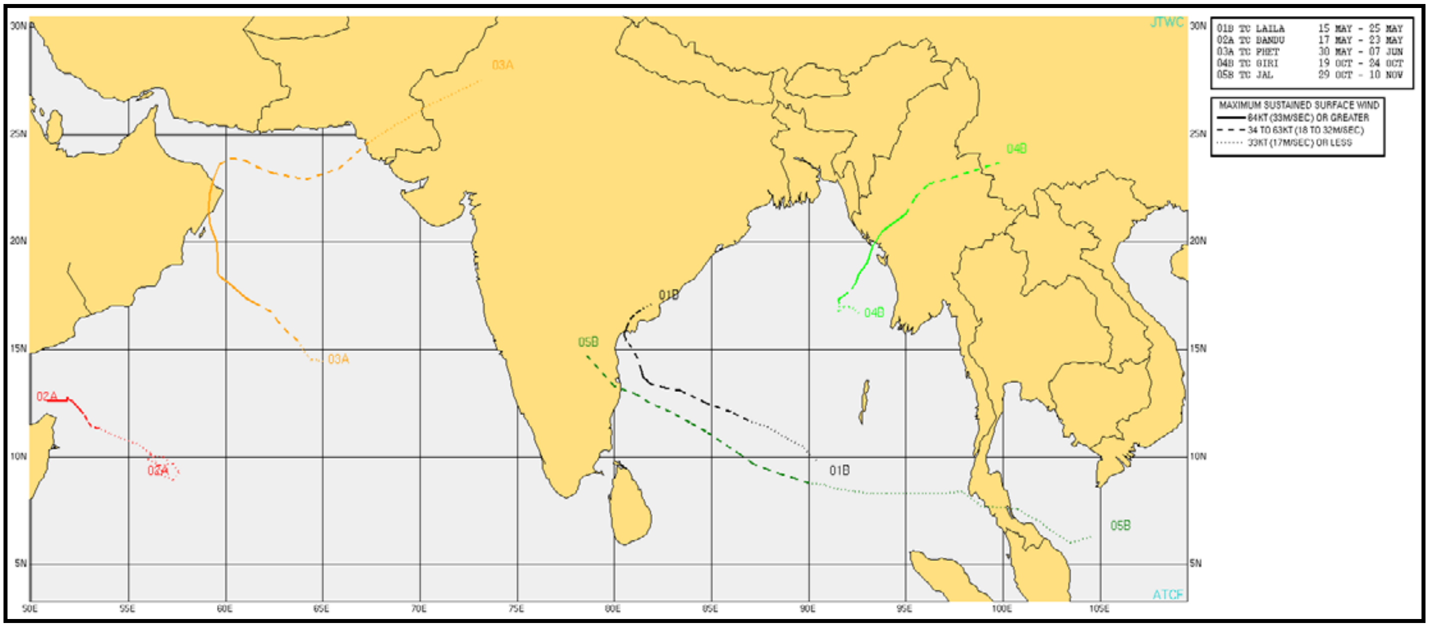


Figure 2-1. North Indian Ocean Tropical Cyclones.

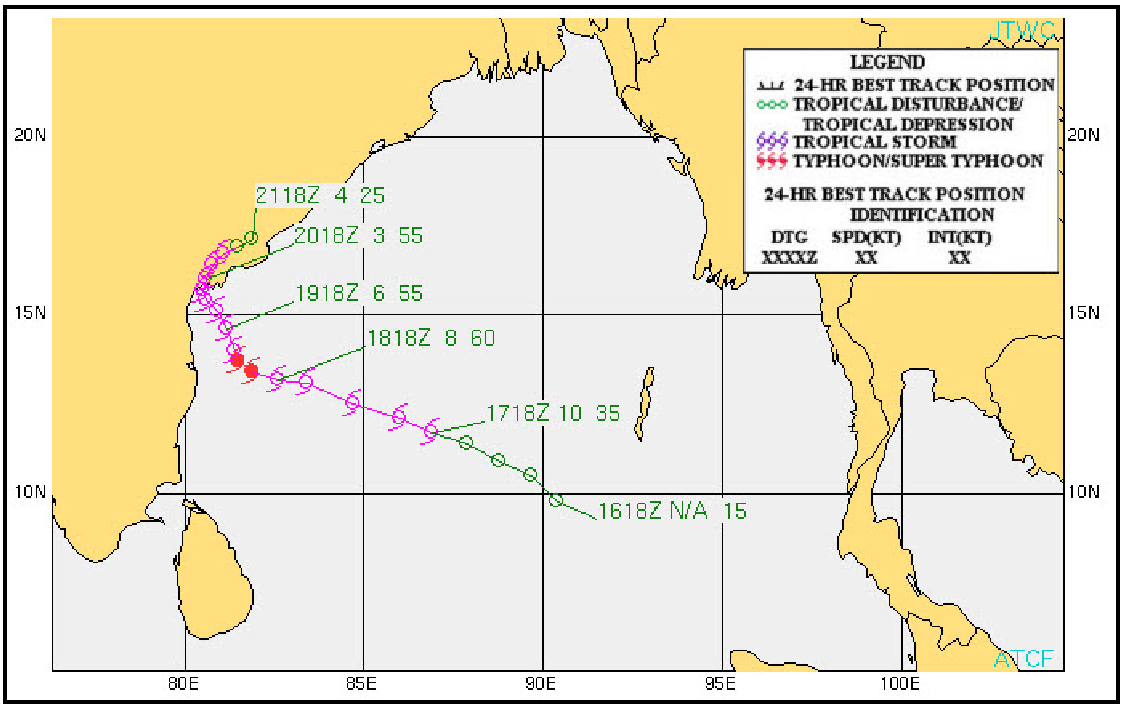
Section 2 Cyclone Summaries

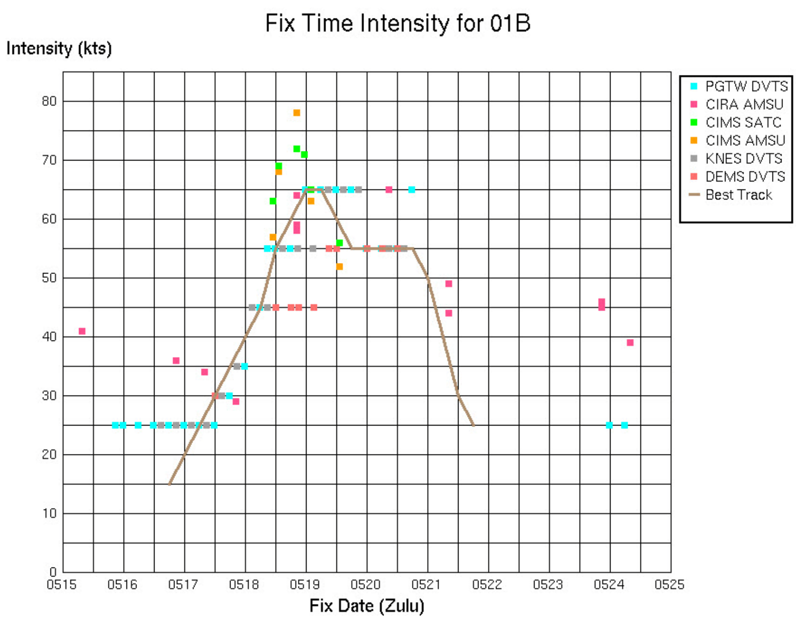
Each cyclone is presented, with the number and basin identifier assigned by JTWC, along with the RSMC assigned cyclone name. Dates are also listed when JTWC first designated various stages of development; as an area of interest (Poor classification), increased potential for development (Fair classification) and development/TC expected (Good classification). Furthermore, the first Tropical Cyclone Formation Alert (TCFA), and the first and final warnings dates are also presented with the number of warnings issued by JTWC. Maximum intensity and the number of warnings issued by JTWC are included as well. Landfall over major landmasses and approximate locations are presented as well.

The JTWC post-event reanalysis best track is also provided for each cyclone. Data included on the best track are position and intensity noted with cyclone symbols and color coded track. Best track position labels include the date-time, track speed in knots, and maximum wind speed in knots. A graph of best track intensity versus time is presented. Fix plots on this graph are color coded by fixing agency.

Tropical Cyclone 01B (Laila)

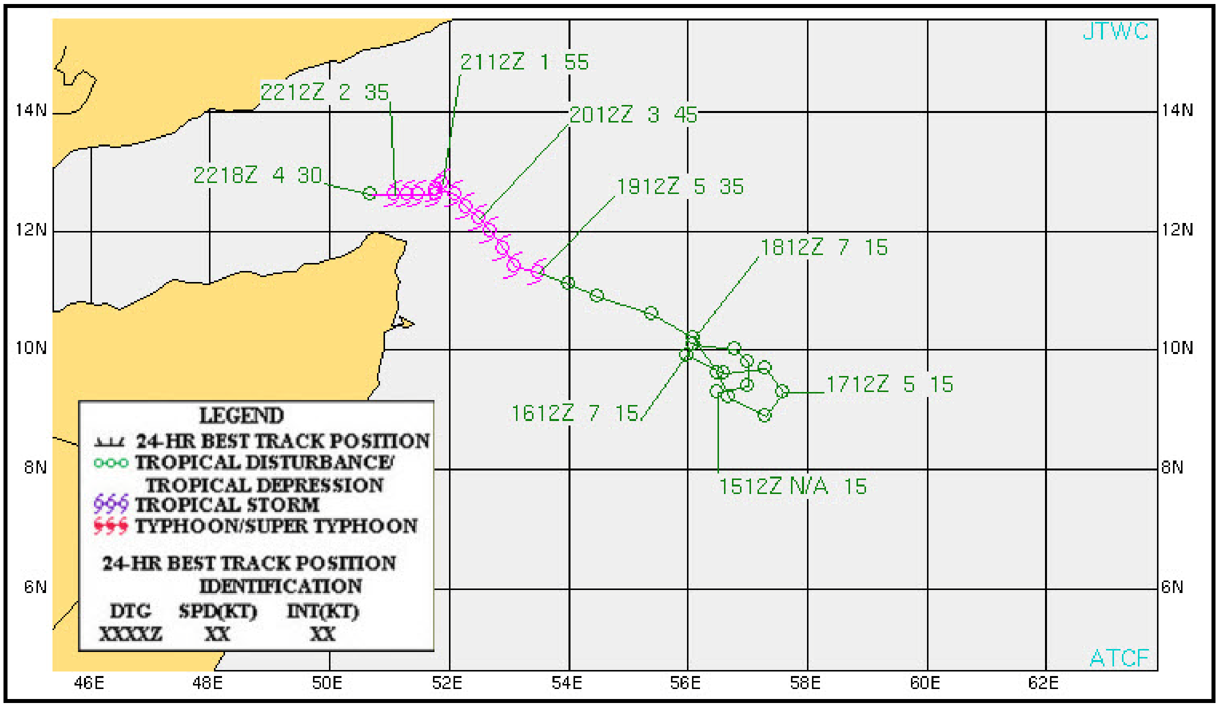
ISSUED POOR:	1800Z 15 May 2010
ISSUED FAIR:	0830Z 17 May 2010
FIRST TCFA:	1500Z 17 May 2010
FIRST WARNING:	1800Z 17 May 2010
LAST WARNING:	1800Z 21 May 2010
MAX INTENSITY:	65 Kts
NUMBER OF WARNINGS:	17

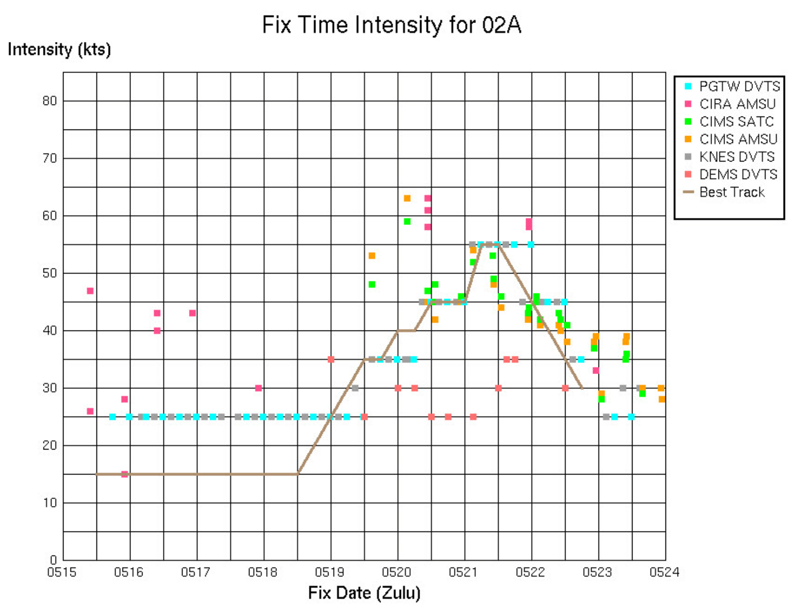




Tropical Cyclone 02A (Bandu)

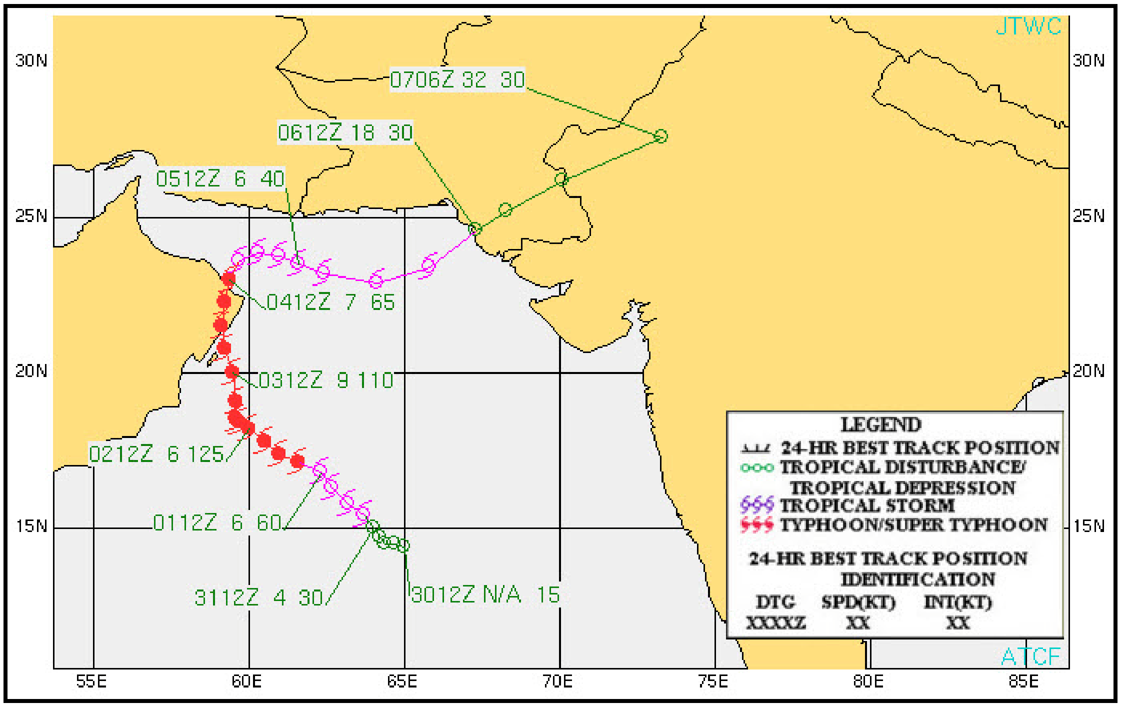
ISSUED POOR:	1800Z 15 May 2010
ISSUED FAIR:	1800Z 18 May 2010
FIRST TCFA:	2230Z 18 May 2010
FIRST WARNING:	1200Z 19 May 2010
LAST WARNING:	2200Z 22 May 2010
MAX INTENSITY:	55 Kts
NUMBER OF WARNINGS:	14

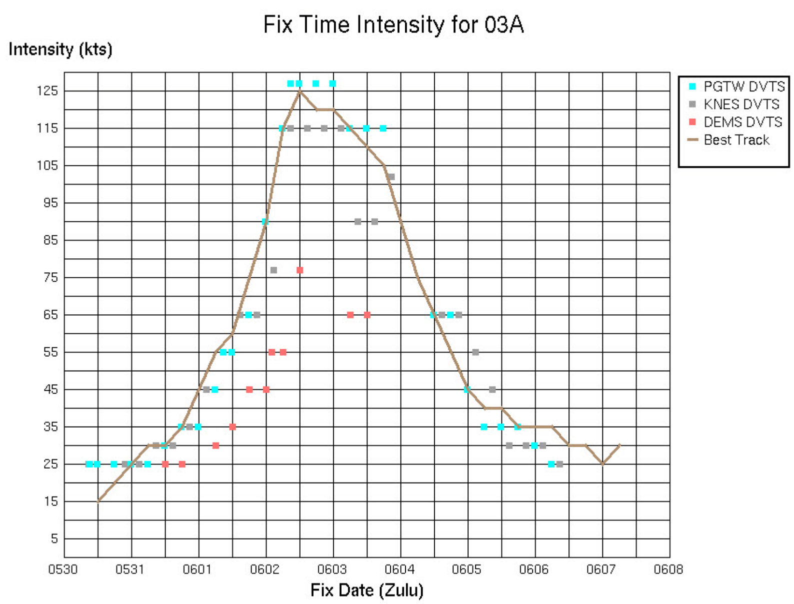




Tropical Cyclone 03A (Phet)

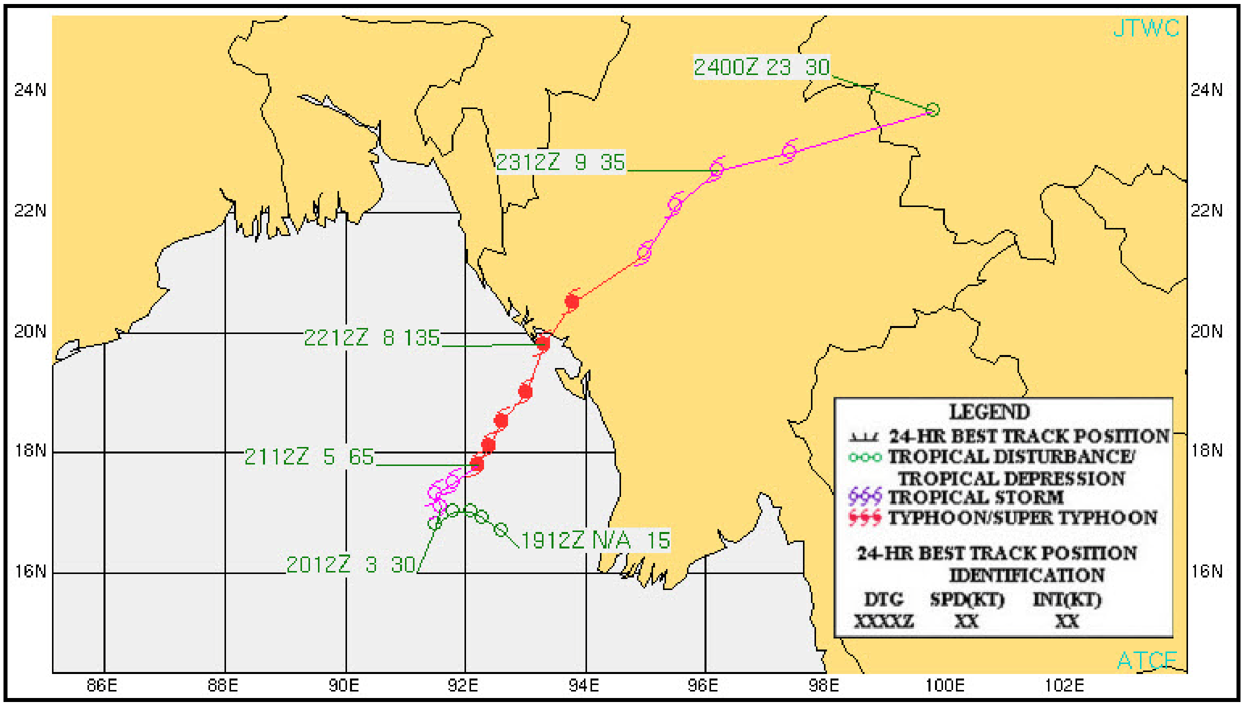
ISSUED POOR:	N/A
ISSUED FAIR:	1800Z 30 May 2010
FIRST TCFA:	0730Z 31 May 2010
FIRST WARNING:	1800Z 31 May 2010
LAST WARNING:	1200Z 06 June 2010
MAX INTENSITY:	125 Kts
NUMBER OF WARNINGS:	24

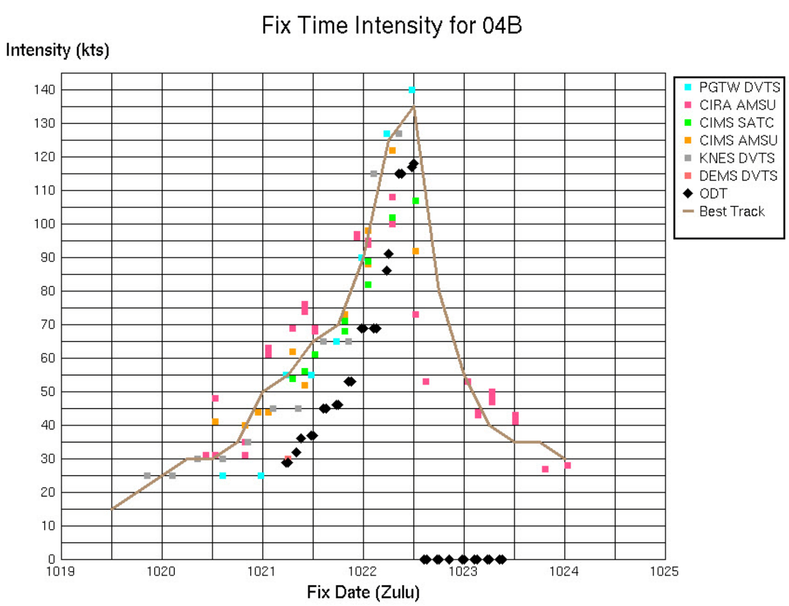




Tropical Cyclone 04B (Giri)

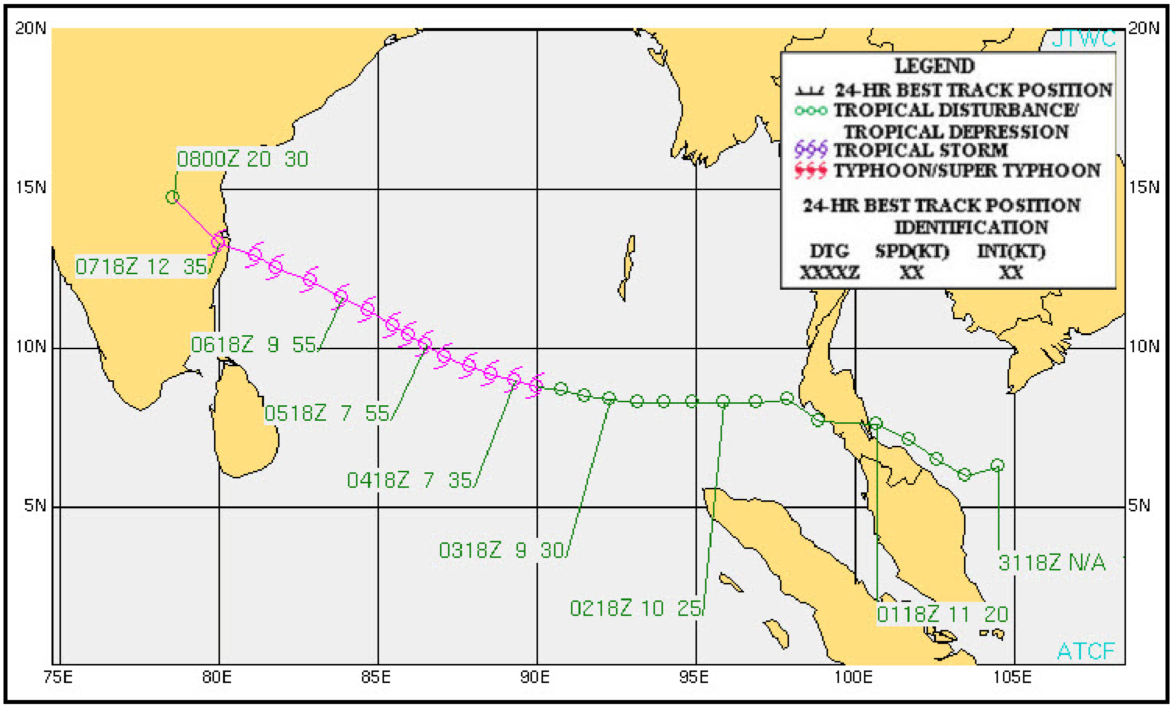
ISSUED POOR:	N/A
ISSUED FAIR:	1800Z 20 Oct 2010
FIRST TCFA:	N/A
FIRST WARNING:	0000Z 21 Oct 2010
LAST WARNING:	1200Z 22 Oct 2010
MAX INTENSITY:	135 Kts
NUMBER OF WARNINGS:	8

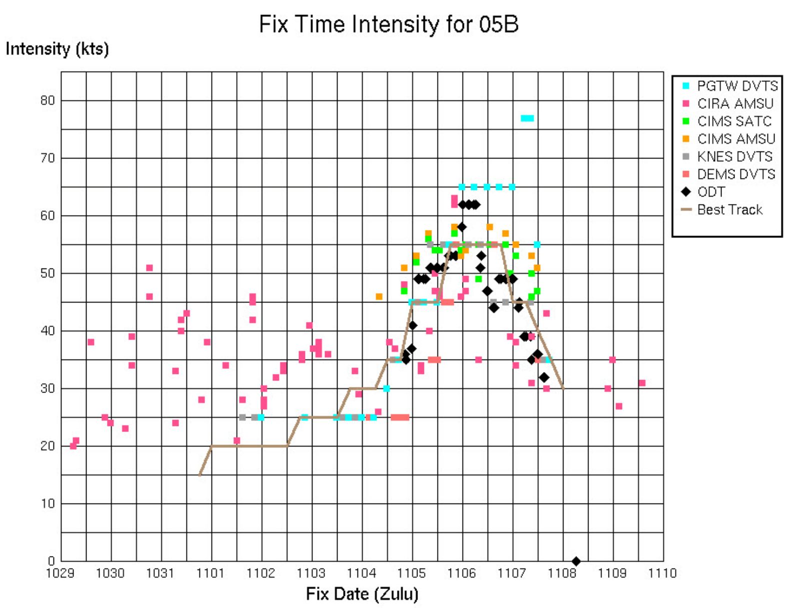




Tropical Cyclone 05B (Jal)

ISSUED POOR:	N/A
ISSUED FAIR:	1800Z 01 Nov 2010
FIRST TCFA:	1200Z 03 Nov 2010
FIRST WARNING:	1800Z 04 Nov 2010
LAST WARNING:	1800Z 07 Nov 2010
MAX INTENSITY:	55 Kts
NUMBER OF WARNINGS:	13





Tropical Cyclone 04B (Giri)

Tropical Cyclone 04B developed in the monsoon trough extending from the Indian subcontinent southeastward across the central Bay of Bengal. JTWC classified the developing circulation as an “invest area” on 19 October and issued the first warning on 20 October at 1800Z. The genesis of TC 04B followed a strong active phase of the Madden-Julian Oscillation observed in the central Indian Ocean during early to mid-October 2010.

During its formation phase, TC 04B tracked slowly northwestward in response to low to middle-level subtropical ridging to the north. Subsequently, a passing mid-latitude trough weakened this ridge, causing the cyclone to meander in a weak steering environment on 19 October. By 20 October, the cyclone began tracking north-northeastward in response to strengthening subtropical ridging to the southeast.

Following its north-northeastward turn, TC 04B rapidly intensified until making landfall in Myanmar as a 135 knot cyclone. Thereafter, the cyclone slowly weakened while progressing inland across central Myanmar. Figure 2-2 shows the final best track and associated intensities for TC 04B.

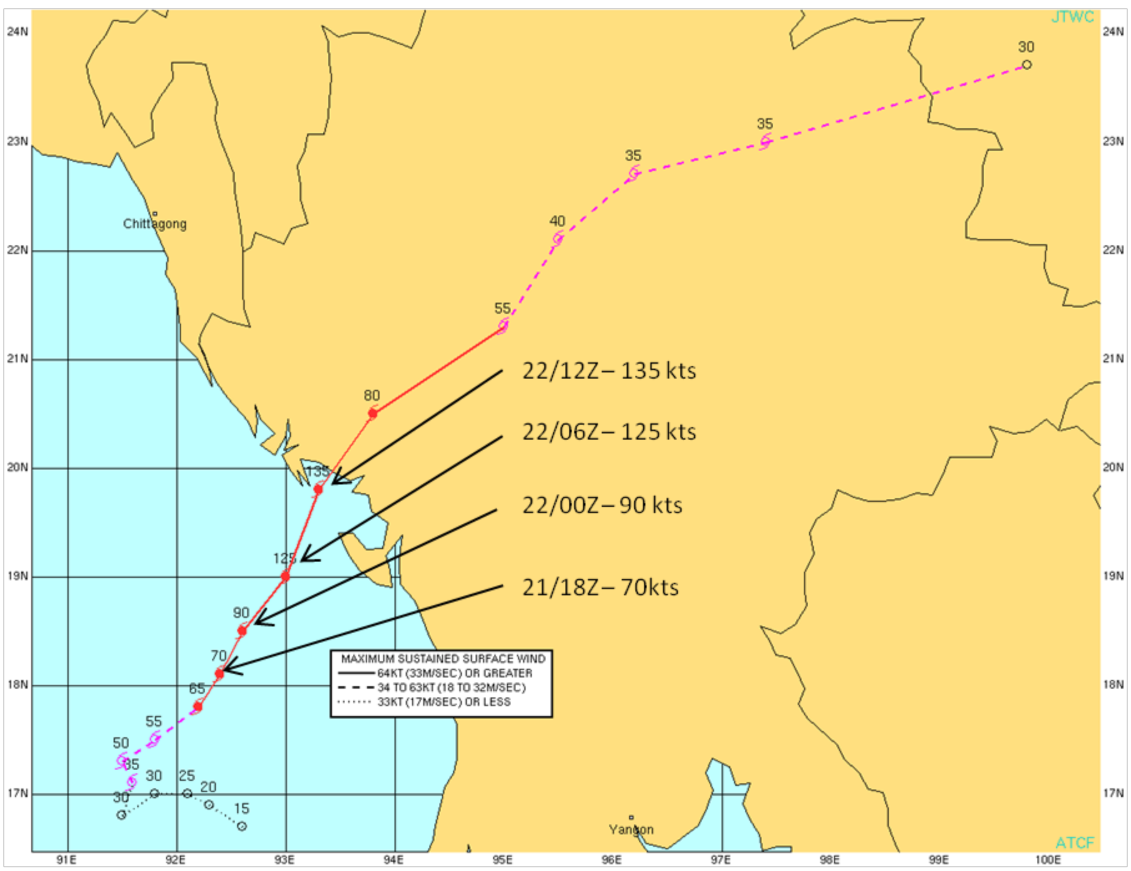


Figure 2-2. Final best track for TC 04B with associated intensities (in knots).

Several environmental factors contributed to the rapid intensification of TC 04B. First, the low level circulation center (LLCC) developed in an area of low vertical wind shear beneath a synoptic-scale, upper-level anticyclone axis. Ridging aloft subsequently amplified over TC 04B

as the cyclone intensified and an upper-level trough dug equatorward over southeastern China, just to the west of a mesoscale anticyclone over Typhoon 15W (Megi) (see figure 2-3 below). Second, strong upper level winds equatorward and poleward of the LLCC set up a classic dual channel outflow regime, which can be inferred from the streamline analysis shown in figure 2-4 (Chen and Gray, 1985). The upper-level trough over southeastern China may have enhanced the poleward outflow channel by providing a favorable outflow “sink”. Finally, ocean heat content values exceeding 75 kJ/cm^2 provided an abundant heat source to fuel the intensifying cyclone.

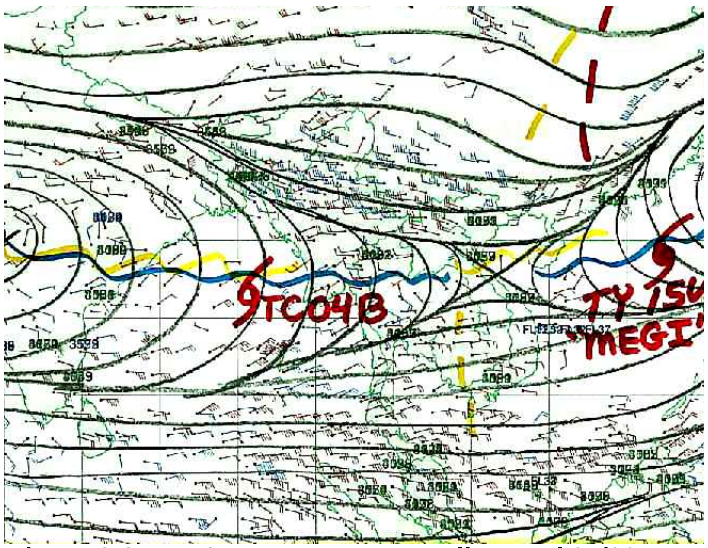


Figure 2-3.JTWC upper-trop streamline anal 21/00Z

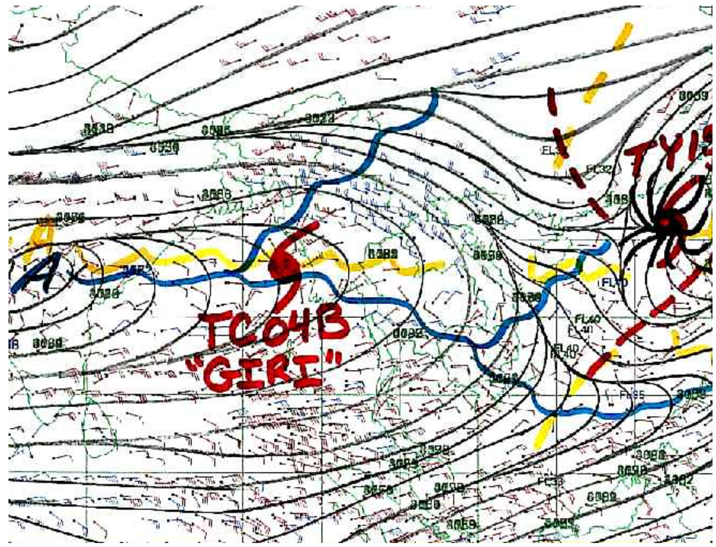


Figure 2-4 JTWC upper-trop streamline anal 22/00Z

Figure 2-3. JTWC upper-tropospheric streamline analyses from 21 October at 0000Z (left) and Figure 2-4 22 October at 0000Z (right) in the vicinity of TC 04B. Strong equatorward and poleward outflow, expansion of upper-level ridging over TC 04B, and equatorward extension of an upper-level trough over southeastern China occurred during this 24 hour period of rapid intensification.

Tropical Cyclone 04B matured as a relatively small cyclone, its upper-level cirrus cloud shield spanning approximately 3 degrees (~180 nautical miles) in diameter throughout the cyclone’s lifecycle. During the period of most pronounced intensity increase - 21 October 1800Z through 22 October 1200Z - the cloud structure of TC 04B underwent significant changes, including organization of symmetrical deep convective banding about the center, development of an eye feature that was at times obscured by the cirrus outflow shield, and emergence of a well-defined cirrus outflow streak poleward of the low-level circulation center around 22/00Z. These structural changes are evident in the satellite imagery series presented in figure 2-5 below.

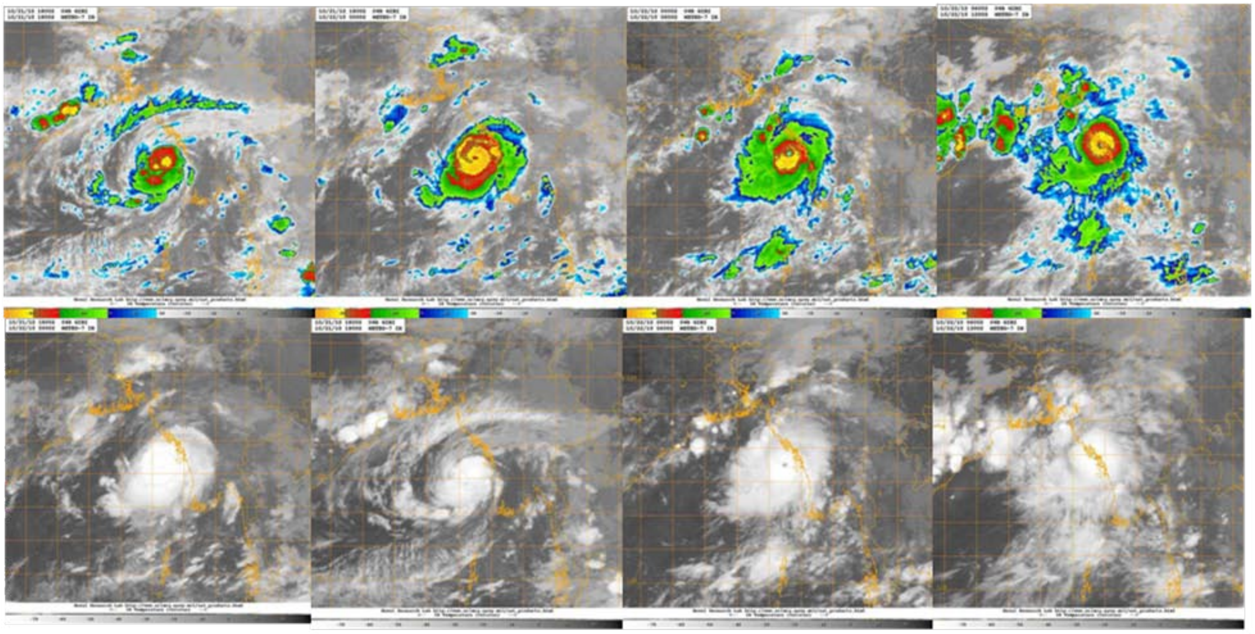


Figure 2-5. Series of storm-centered, enhanced infrared satellite images for the rapid intensification period from the 21 October at 1800Z through 22 October 1200Z for TC 04B (images courtesy NRL TC page). The emergence of a cirrus outflow streak evident in the 22/00Z image suggests that enhanced poleward outflow within an expanding upper-level ridge toward a downstream upper-level trough aided the rapid intensification of TC 04B.

Rapid structural changes within TC 04B complicated application of the Dvorak technique. Indeed, the JTWC Satellite Analyst issued a correction to the 220530Z Dvorak T-number estimate after determining that the initial fix estimate was too low. Despite complications involved in applying the Dvorak technique, the fix intensity versus time graph displayed in figure 2-6 below indicates that subjective Dvorak intensity fixes prepared by JTWC and other fixing agencies did, for the most part, “capture” the rapid intensity change. However, automated intensity fix solutions during the peak intensity period from 22 October at 0600Z until 22 October 1200Z were mostly lower than the subjective estimates, perhaps due to the documented sensitivities of these automated intensity fix methods to storm structure and satellite resolution and to the limitations of their foundational mathematical algorithms (Brueske and Velden, 2003; Demuth et al, 2004; Olander and Velden, 2007).

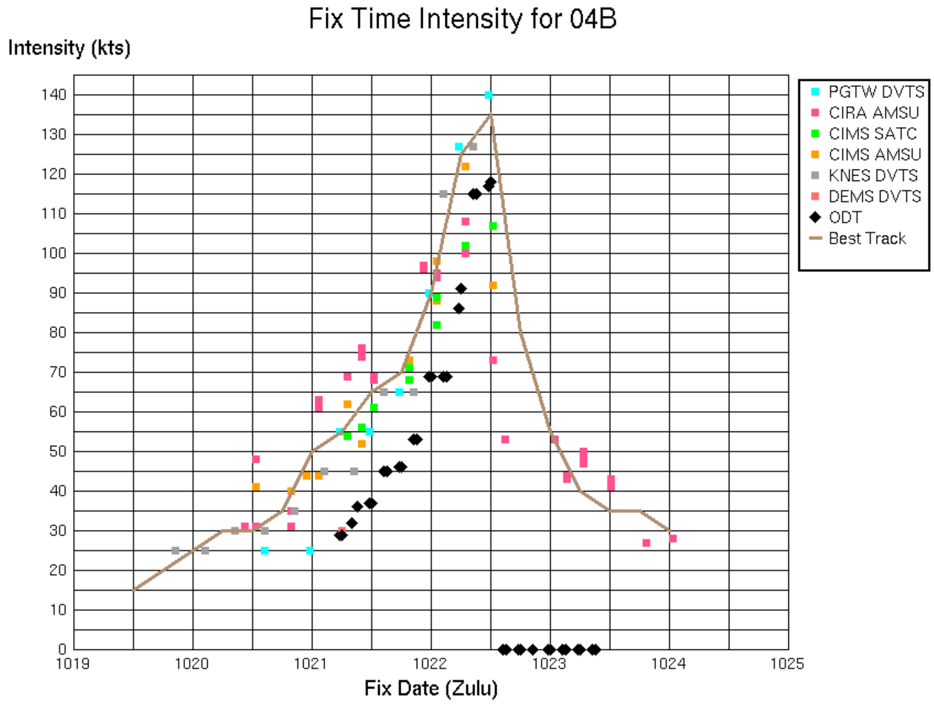


Figure 2-6. Subjective (PGTW, KNES, and DEMS) and automated fix intensities (CIRA and CIMS) versus final best track intensities (gold line).

JTWC intensity forecasts between 20 October at 12Z and 21 October at 12Z called for TC 04B to either slowly intensify or maintain intensity prior to landfall. The forecasts were in line with STIPS statistical-dynamical intensity forecast guidance and indicators from most of the numerical forecast guidance. Although global models typically do not forecast tropical cyclone intensity accurately, they can provide reliable indicators of the expected intensity trend. However, in the case of TC 04B, the NOGAPS, GFS, and UKMET global models forecasted steady intensity or weakening trend prior to landfall (see figure 2-7).

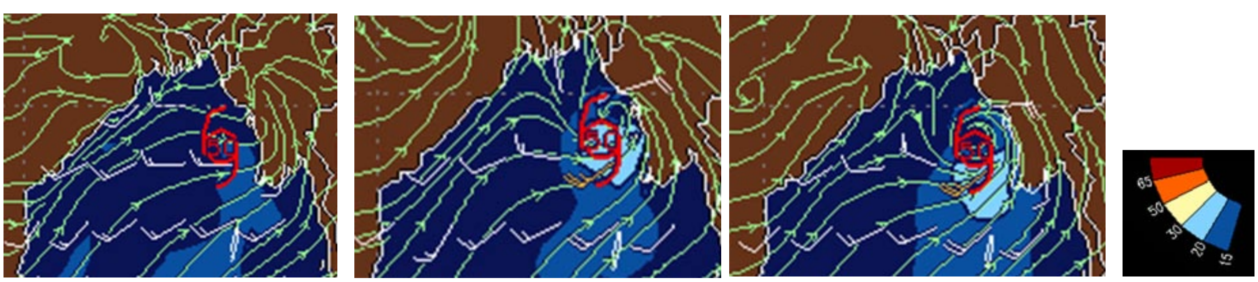


Figure 2-7. 18-hour surface wind field forecasts for TC 04B initialized at 1200Z on 21 October 2010 (from left: GFS, NOGAPS, and UKMET global models). The TC symbol with “50” inset represents the JTWC analysis position and intensity estimate (50 knots) at 1200Z on 21 October. Wind speed color contours are consistent with the key at right (in knots). The verifying intensity of TC 04B at 0600Z on 21 October 2010 (the forecast time shown here) was 125 knots (image source: JTWC WxMap, developed by Dr. Michael Fiorino).

The GFDN intensity forecasts did predict a more rapid rate of intensification than other model guidance, but GFDN-forecasted peak intensities still significantly undershot the best track maximum intensity of 135 knots. Given that the higher resolution GFDN predicted a greater rate of intensification than the global models, it is possible that the cyclone’s small size contributed to under-forecasting of the intensity trend by the lower resolution global dynamical models.

Errors in the intensity analysis at least partially contributed to the noted low biases in statistical and numerical model forecast guidance and JTWC subjective forecasts during the cyclone's intensification phase. Rapid changes in the developing cyclone's structure complicated real-time analysis of the cyclone's intensity, resulting in intensity estimates that were 5 to 15 knots lower than the retrospective final best track estimates at several synoptic times. Note the discrepancies between JTWC and ST11 initial intensities, which match the real-time intensity analyses, and the final reanalysis best track intensities shown in figure 2-8. Better real-time best track intensity estimates would have altered ST11 forecasts through the scheme's incorporation of prior intensity trend (Knaff et al, 2005) and potentially improved NOGAPS and GFDN analyses through the impact of the tropical cyclone bogus data provided by JTWC. However, it's unclear how much impact improving the real-time intensity analyses would have on the low biases in the statistical and dynamical forecasts, but researchers are currently investigating this.

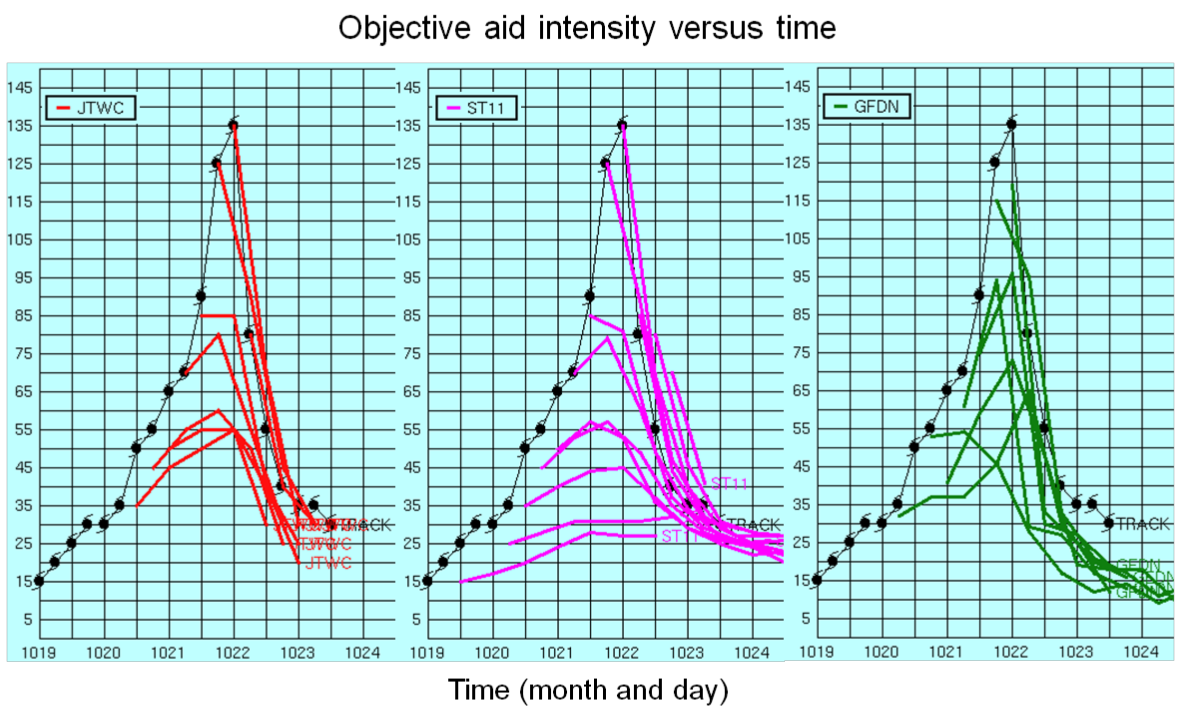


Figure 2-8. Objective aid time intensity graph showing JTWC subjective, STIPS statistical-dynamical (ST11), and GFDN dynamical, intensity forecast output for TC 04B. The black line with TC symbols represents final reanalysis best track intensities.

TC 04B demonstrated both the importance of formulating the accurate intensity analyses and the difficulty of forecasting tropical cyclone intensity change when synoptic and model guidance diverge. Although synoptic conditions favored intensification of TC 04B prior to landfall, primary statistical-dynamical and numerical model forecast guidance indicating minimal intensification clearly influenced the subjective forecasts. Unfortunately, there is currently no consistent method to identify situations in which the primary intensity forecast guidance may contain significant error. Developing such a method, whether based on a model ensemble or subjective criteria, could provide significant benefit to forecast operations during future scenarios like the one explored here.

References:

Brueske, K. F. and C. S. Velden, 2003: Satellite-based tropical cyclone intensity estimation using the NOAA-KLM series Advanced Microwave Sounding Unit (AMSU). *Mon. Wea. Rev.,* **131**, 687-697.

Chen, L. and W.M. Gray, 1985: Global view of the upper level outflow patterns associated with tropical cyclone intensity changes during FGGE. Department of Atmospheric Science Paper 392, Colorado State University, Fort Collins, Colorado, 126 pp.

Demuth, J. L., M. DeMaria, J. A. Knaff and T. H. Vonder Haar, 2004: Evaluation of Advanced Microwave Sounding Unit tropical-cyclone intensity and size estimation algorithms. *J. Applied Met.*, **43**, 282-296.

Knaff, J.A., C.R. Sampson, and M. DeMaria, 2005: An operational statistical typhoon intensity prediction scheme for the western North Pacific. *Wea. Forecasting*, **20**, 688-698.

Olander, T. L. and C. S. Velden, 2007: The Advanced Dvorak Technique: Continued development of an objective scheme to estimate tropical cyclone intensity using geostationary infrared satellite imagery. *Wea. Forecasting*, **22**, 287-298.

Chapter 3 South Pacific and South Indian Ocean Tropical Cyclones

This chapter contains information on South Pacific and South Indian Ocean TC activity that occurred during the 2010 tropical cyclone season (1 July 2009 – 30 June 2010) and the monthly distribution of TC activity summarized for 1975 - 2010.

Section 1 Informational Tables

Table 3-1 is a summary of TC activity in the Southern Hemisphere during the 2010 season. Table 3-2 provides the monthly distribution of Tropical Cyclone activity summarized for 1975 - 2010.

Table 3-1

SOUTHERN HEMISPHERE TROPICAL CYCLONES FOR 2010

(01 JULY 2009 - 30 JUNE 2010)

TC	NAME*	PERIOD		WARNINGS ISSUED	EST MAX SFC WINDS KTS	MSLP (MB)**
01S	Anja	14 Nov / 0600Z	18 Nov / 1200Z	10	105	944
02S	Bongani	23 Nov / 0600Z	25 Nov / 1800Z	6	40	993
03S	Cleo	07 Dec / 0000Z	14 Dec / 0000Z	13	115	937
04P	Mick	12 Dec / 1200Z	15 Dec / 1200Z	7	65	974
05S	David	13 Dec / 0600Z	25Dec / 1800Z	15	55	982
06S	Laurence	13 Dec / 0600Z	21 Dec / 1200Z	15	130	926
07S	Edzani	06 Jan / 0000Z	14 Jan / 1800Z	18	140	918
08S	Magda	20 Jan / 1800Z	22 Jan / 1800Z	5	65	974
09P	Olga	23 Jan / 0000Z	30 Jan / 0000Z	10	45	989
10P	Nisha	27 Jan / 1200Z	30 Jan / 0000Z	6	55	982
11S	N/A	27 Jan / 1800Z	30 Jan / 0600Z	6	35	996
12P	Oli	01 Feb / 0000Z	06 Feb / 1200Z	12	115	937
13S	Fami	02 Feb / 0600Z	02 Feb / 1800Z	2	50	985
14P	Pat	07 Feb / 1800Z	11 Feb / 1800Z	9	90	956
15P	Rene	11 Feb / 0000Z	16 Feb / 1800Z	17	100	948
16S	Gelane	16 Feb / 0000Z	21 Feb / 1800Z	18	125	929
17P	Sarah	21 Feb / 1800Z	22 Feb / 1800Z	3	35	996
18S	Hubert	10 Mar / 0000Z	10 Mar / 1200Z	2	50	985
19P	Tomas	11 Mar / 1200Z	17 Mar / 0600Z	13	115	937
20P	Ului	11 Mar / 1800Z	20 Mar / 1800Z	21	140	918
21S	Imani	22 Mar / 1800Z	26 Mar / 1800Z	9	80	963
22P	Paul	27 Mar / 1800Z	30 Mar / 0600Z	6	70	970
23S	Robyn	02 Apr / 0600Z	06 Apr / 0600Z	9	65	974
24S	Sean	22 Apr / 1200Z	25 Apr / 0000Z	7	60	978

*As designated by the responsible RSMC

**MSLP converted from estimated maximum winds using Knaff-Zehr wind pressure relationship. Number of warnings includes amended warnings.

Table 3-2													
DISTRIBUTION OF SOUTH PACIFIC AND SOUTH INDIAN OCEAN TROPICAL CYCLONES													
FOR 1958 - 2010													
YEAR	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	TOTALS
1958 - 1977 AVERAGE*													
-	-	-	-	0.4	1.5	3.6	6.1	5.8	4.7	2.1	0.5	-	24.7
1981 - 2010													
1981	0	0	0	1	3	2	6	5	3	3	1	0	24
1982	1	0	0	1	1	3	9	4	2	3	1	0	25
1983	1	0	0	1	1	3	5	6	3	5	0	0	25
1984	1	0	0	1	2	5	5	10	4	2	0	0	30
1985	0	0	0	0	1	7	9	9	6	3	0	0	35
1986	0	0	1	0	1	1	9	9	6	4	2	0	33
1987	0	1	0	0	1	3	6	8	3	4	1	1	28
1988	0	0	0	0	2	3	5	5	3	1	2	0	21
1989	0	0	0	0	2	1	5	8	6	4	2	0	28
1990	2	0	1	1	2	2	4	4	10	2	1	0	29
1991	0	0	1	1	1	3	2	5	5	2	1	1	22
1992	0	0	1	1	2	5	4	11	3	2	1	0	30
1993	0	0	1	1	0	5	7	7	2	2	2	0	27
1994	0	0	0	0	2	4	8	4	9	3	0	0	30
1995	0	0	0	0	2	2	5	4	5	4	0	0	22
1996	0	0	0	0	1	3	7	6	6	4	1	0	28
1997	1	1	1	2	2	6	9	8	3	1	3	1	38
1998	1	0	0	3	2	3	7	9	6	6	0	0	37
1999	1	0	1	1	1	6	6	8	7	2	0	0	33
2000	0	0	0	0	0	3	6	5	7	6	0	0	27
2001	0	1	0	0	1	1	4	6	2	5	0	1	21
2002	0	0	0	2	4	1	4	5	4	2	3	0	25
2003	0	0	1	0	2	5	5	7	5	2	1	1	29
2004	0	0	0	1	1	3	6	3	7	1	1	0	23
2005	0	0	1	1	2	2	7	7	4	2	0	0	26
2006	6	5	5	3	0	0	0	0	0	1	2	1	23
2007	0	0	0	0	1	2	2	5	6	6	1	1	24
2008	1	0	0	0	3	4	7	5	6	3	0	0	29
2009	0	0	0	1	2	2	7	4	8	3	0	0	27
2010	0	0	0	0	2	4	5	6	5	2	0	0	24
(1981 - 2010)													
MEAN	0.5	0.3	0.5	0.7	1.6	3.1	5.7	6.1	4.9	3.0	0.9	0.2	27.4
CASES	15	8	14	22	47	94	171	183	146	90	26	7	823
* (GRAY, 1978)													
The criteria used in TABLE 2-2 are as follows:													
1) If a tropical cyclone was first warned on during the last two days of a particular month and continued into the next month for longer than two days, then that system was attributed to the second month													
2) If a tropical cyclone was warned on prior to the last two days of a month, it was attributed to the first month, regardless of how long the system lasted.													
3) If a tropical cyclone began on the last day of the month and ended on the first day of the next month, that system was attributed to the first month. However, if a tropical cyclone began on the last day of the month and continued into the next month for only two days, then it was attributed to the second month.													

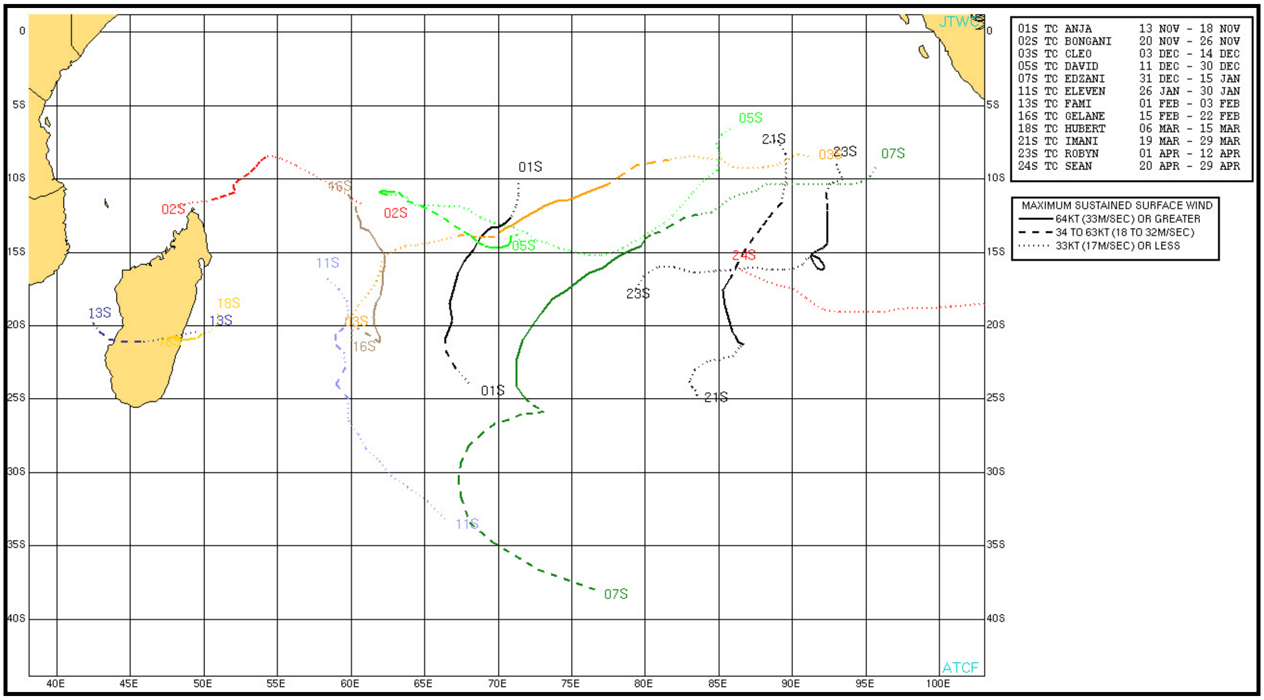


Figure 3-1. Southern Indian Ocean Tropical Cyclones.

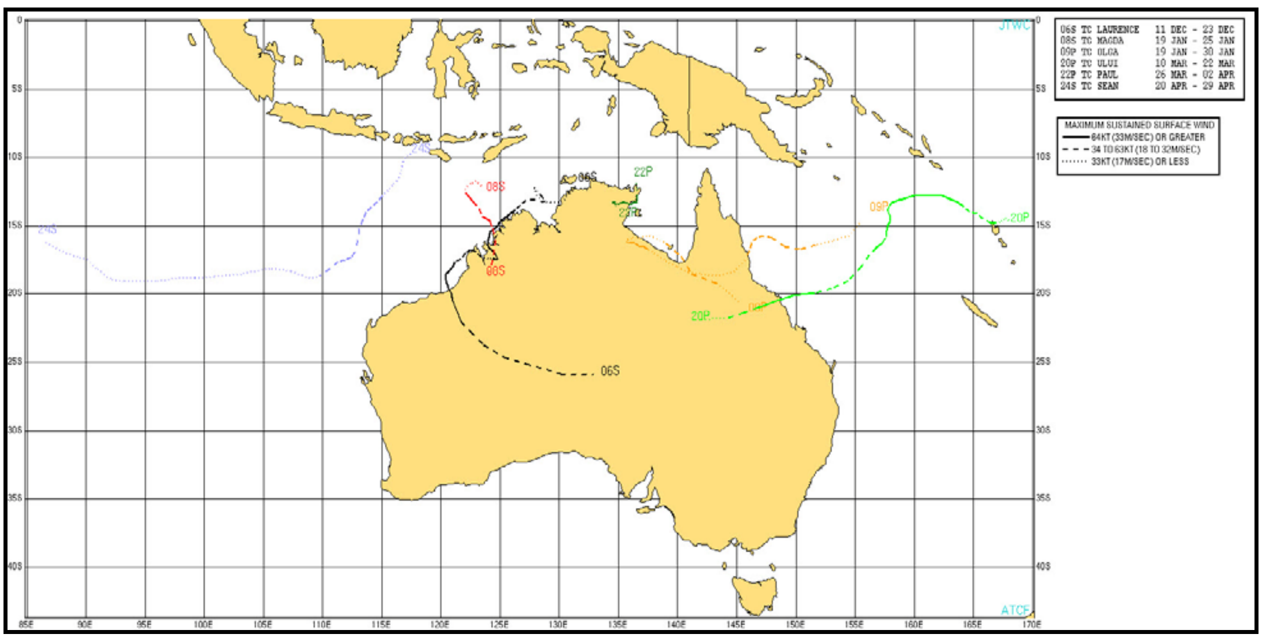


Figure 3-2. Australia Region Tropical Cyclones.

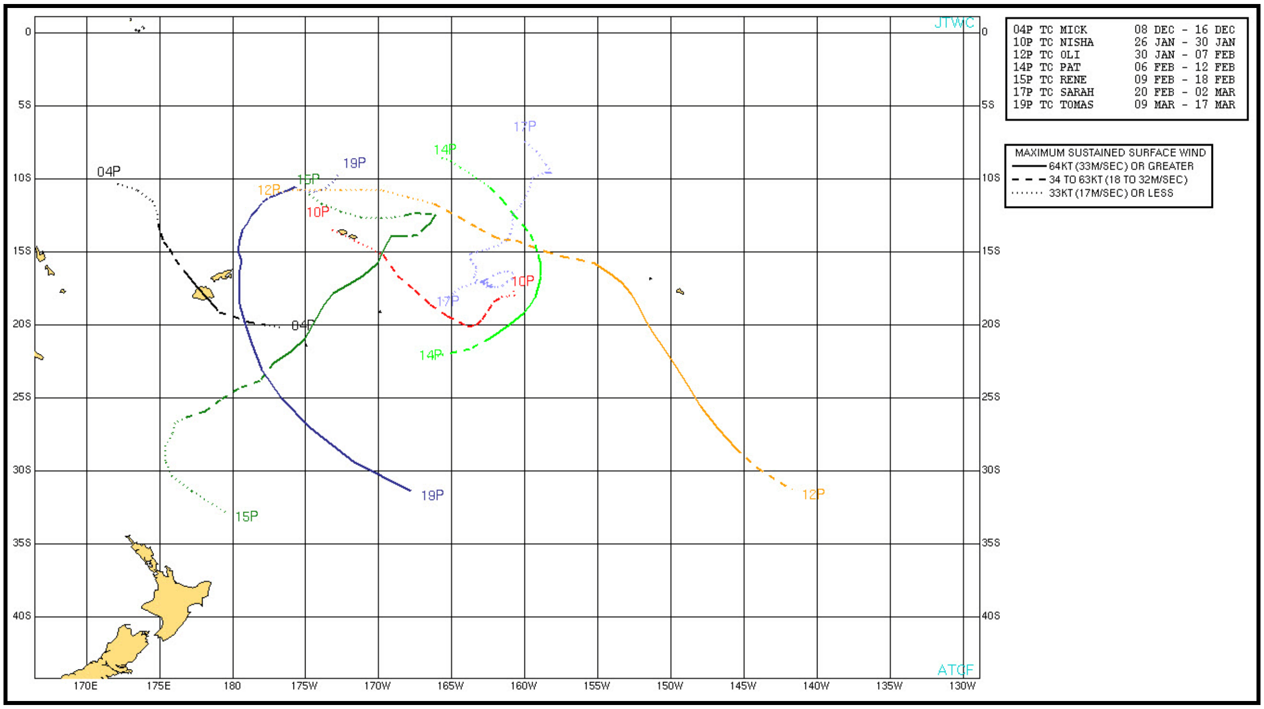


Figure 3-3. Southern Pacific Tropical Cyclones.

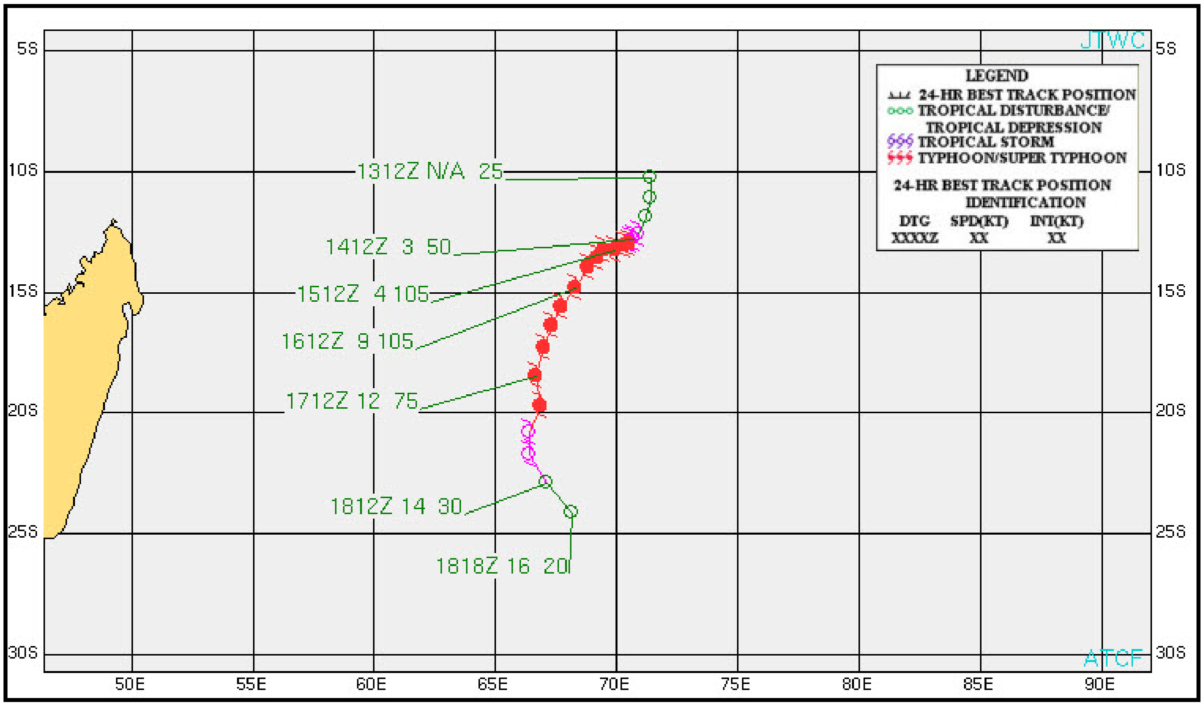
Section 2 Cyclone Summaries

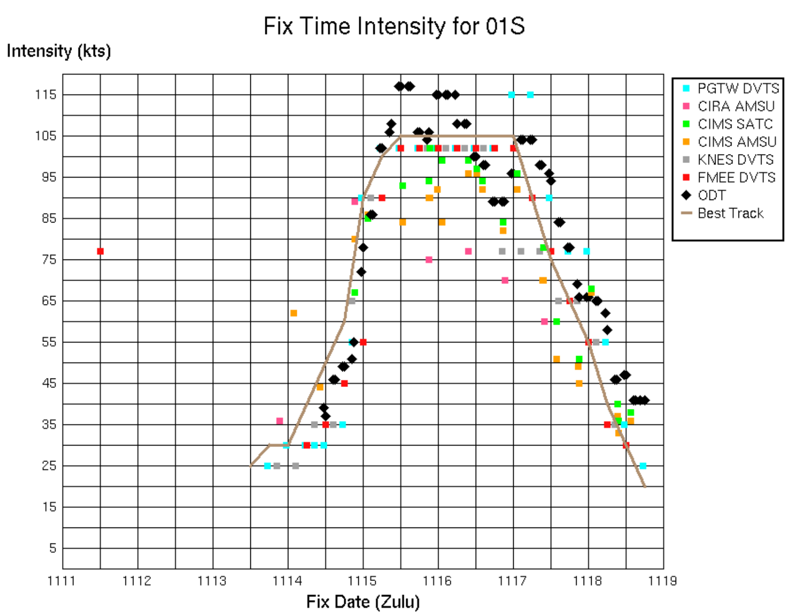
Each cyclone is presented, with the number and basin identifier assigned by JTWC, along with the RSMC assigned cyclone name. Dates are also listed when JTWC first designated various stages of development; as an area of interest (Poor classification), increased potential for development (Fair classification) and development/TC expected (Good classification). Furthermore, the first Tropical Cyclone Formation Alert (TCFA), and the first and final warnings dates are also presented with the number of warnings issued by JTWC. Maximum intensity and the number of warnings issued by JTWC are included as well. Landfall over major landmasses and approximate locations are presented as well.

The JTWC post-event reanalysis best track is also provided for each cyclone. Data included on the best track are position and intensity noted with cyclone symbols and color coded track. Best track position labels include the date-time, track speed in knots, and maximum wind speed in knots. A graph of best track intensity versus time is presented. Fix plots on this graph are color coded by fixing agency.

Tropical Cyclone 01S (Anja)

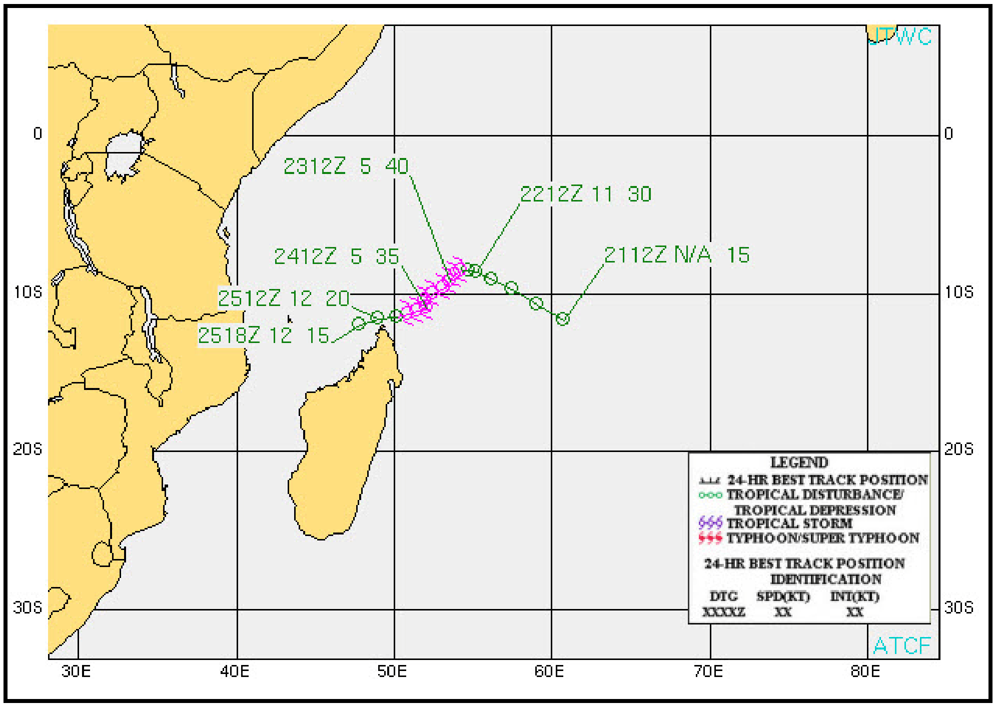
ISSUED POOR:	1800Z 11 Nov 2009
ISSUED FAIR:	2030Z 13 Nov 2009
FIRST TCFA:	0000Z 14 Nov 2009
FIRST WARNING:	0600Z 14 Nov 2009
LAST WARNING:	1200Z 18 Nov 2009
MAX INTENSITY:	105 Kts
NUMBER OF WARNINGS:	10

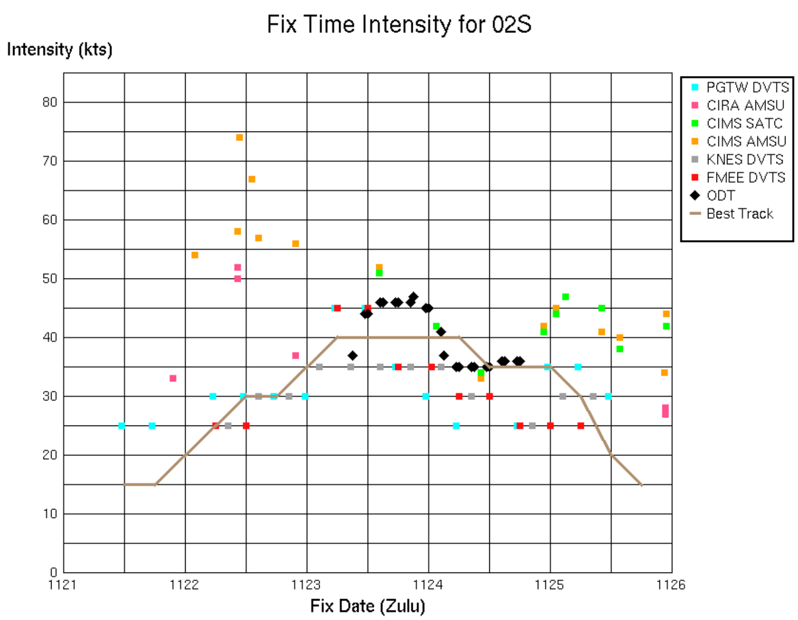




Tropical Cyclone 02S (Bongani)

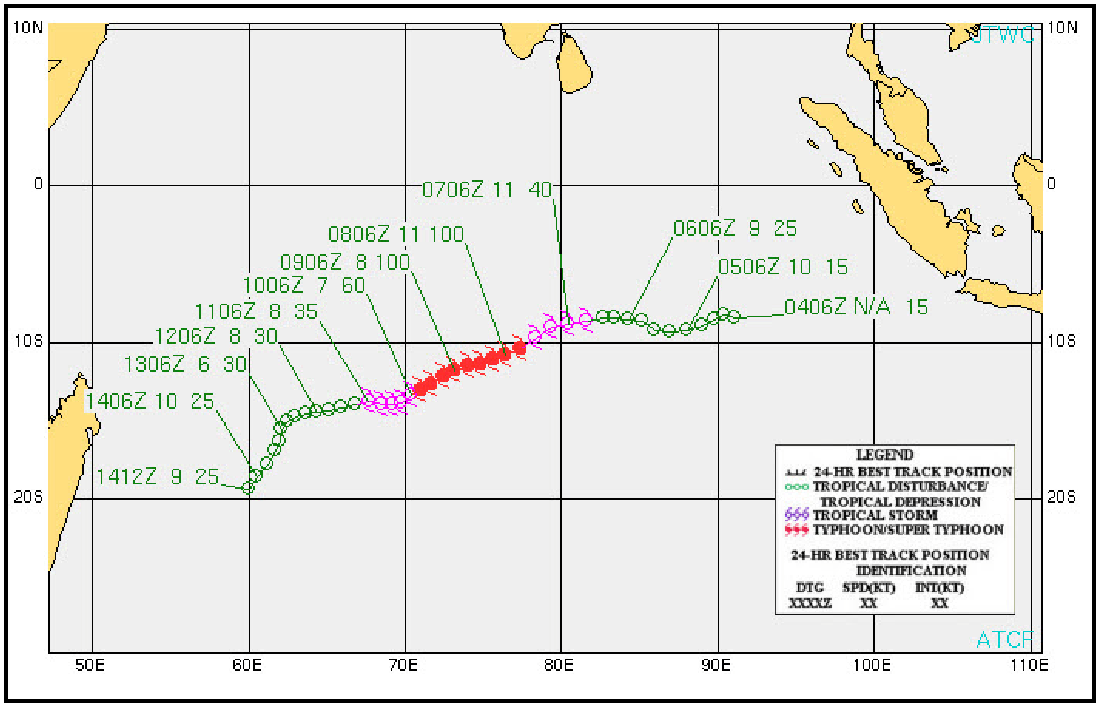
ISSUED POOR:	1800Z 21 Nov 2009
ISSUED FAIR:	1130Z 22 Nov 2009
FIRST TCFA:	N/A
FIRST WARNING:	0600Z 23 Nov 2009
LAST WARNING:	1800Z 25 Nov 2009
MAX INTENSITY:	40 Kts
NUMBER OF WARNINGS:	6

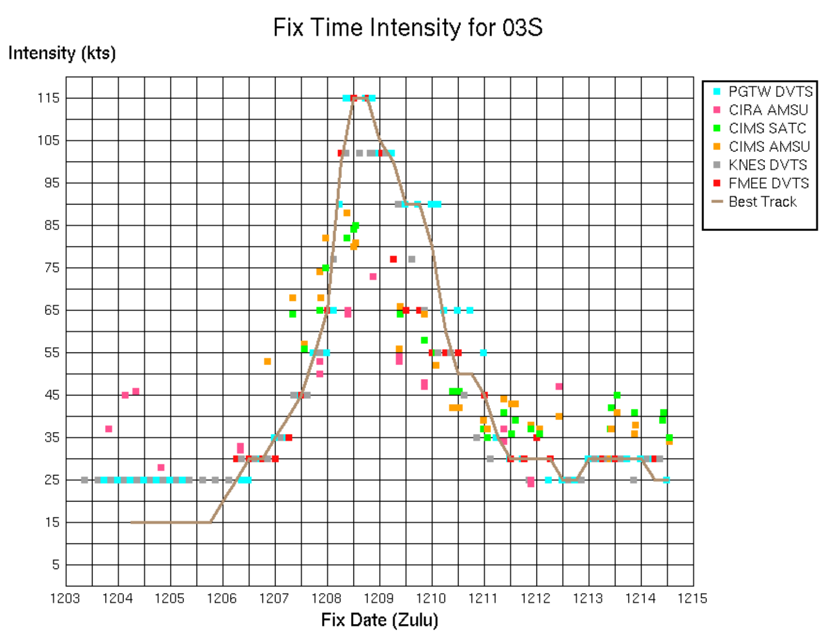




Tropical Cyclone 03S (Cleo)

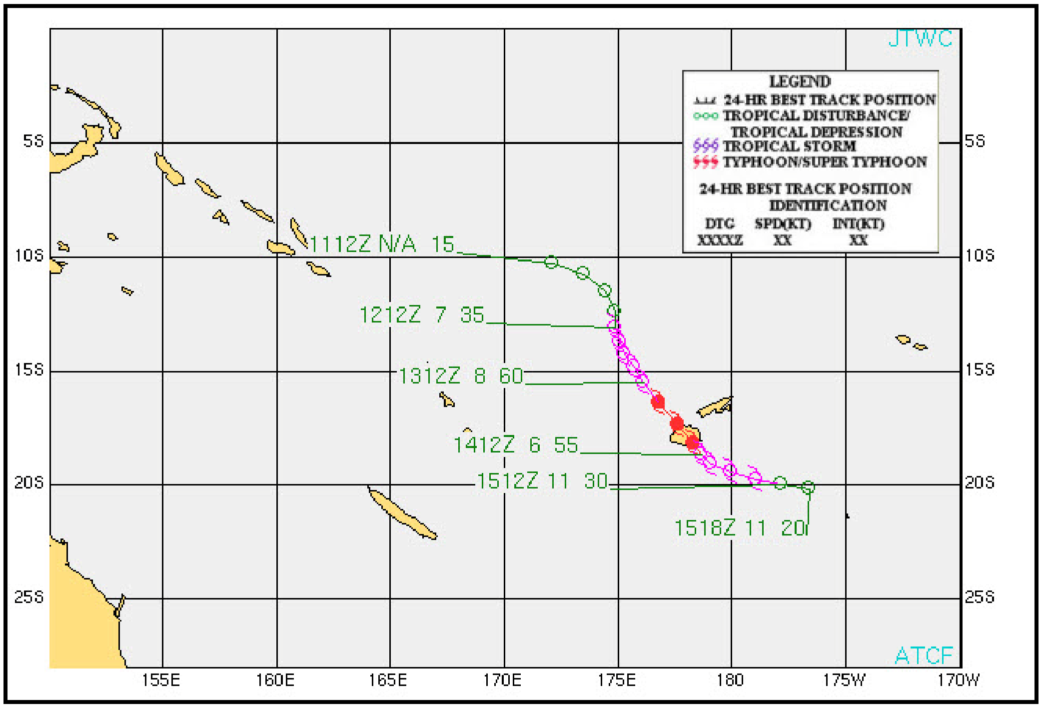
ISSUED POOR:	1800Z 03 Dec 2009
ISSUED FAIR:	0630Z 06 Dec 2009
FIRST TCFA:	1130Z 06 Dec 2009
FIRST WARNING:	0000Z 07 Dec 2009
LAST WARNING:	0000Z 14 Dec 2009
MAX INTENSITY:	115 Kts
NUMBER OF WARNINGS:	13

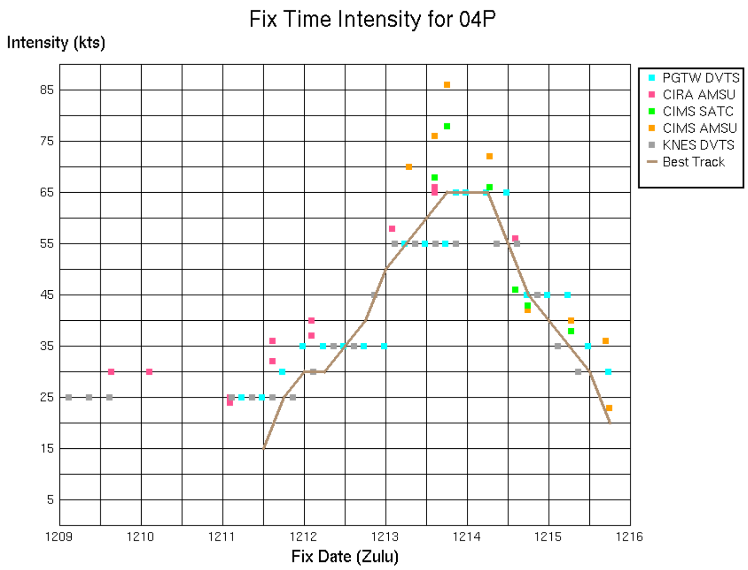




Tropical Cyclone 04P (Mick)

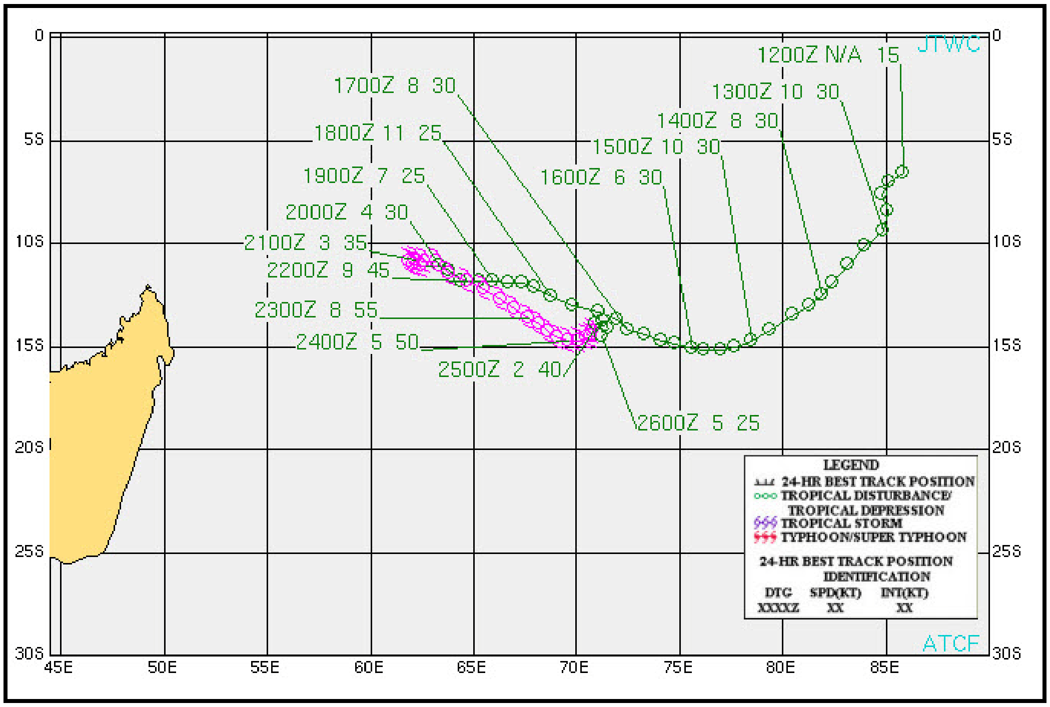
ISSUED POOR:	0600Z 09 Dec 2009
ISSUED FAIR:	0600Z 11 Dec 2009
FIRST TCFA:	0130Z 12 Dec 2009
FIRST WARNING:	1200Z 12 Dec 2009
LAST WARNING:	1200Z 15 Dec 2009
MAX INTENSITY:	65 Kts
NUMBER OF WARNINGS:	7

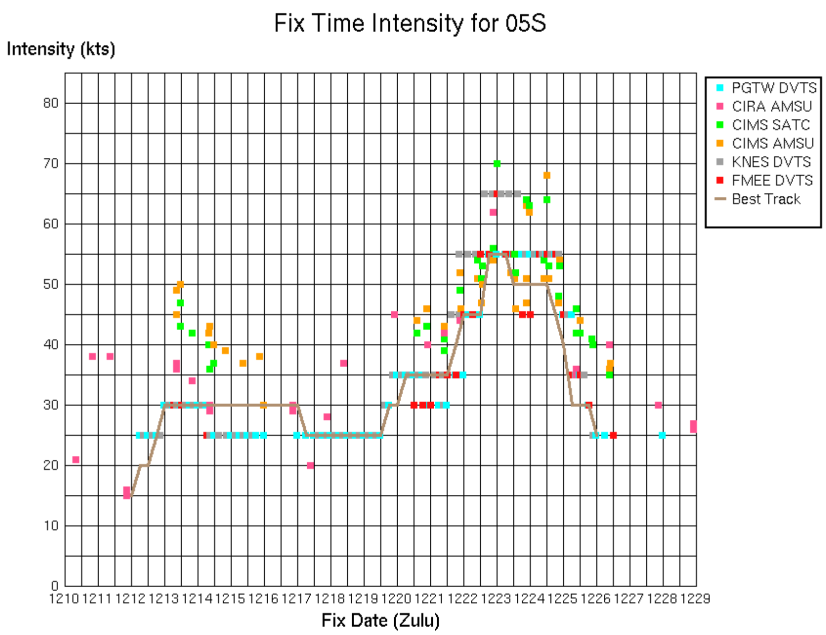




Tropical Cyclone 05S (David)

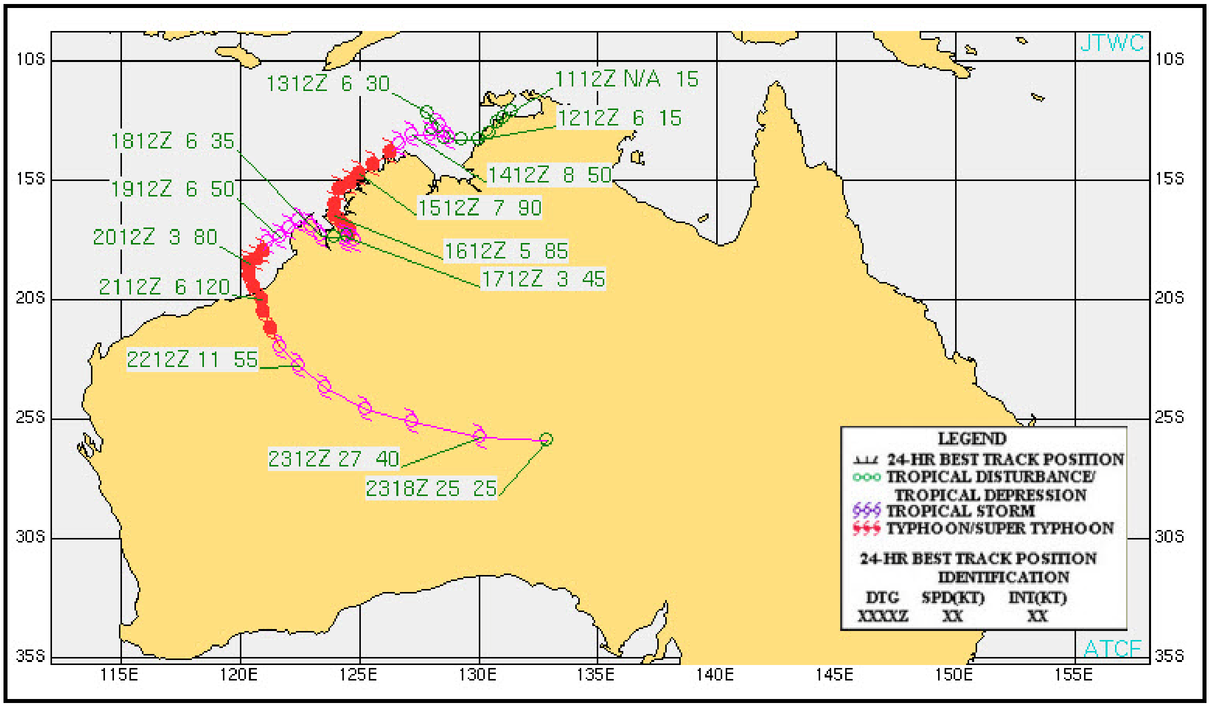
ISSUED POOR:	N/A
ISSUED FAIR:	1030Z 12 Dec 2009
FIRST TCFA:	2100Z 12 Dec 2009
FIRST WARNING:	0600Z 13 Dec 2009
LAST WARNING:	1800Z 25 Dec 2009
MAX INTENSITY:	55 Kts
NUMBER OF WARNINGS:	15

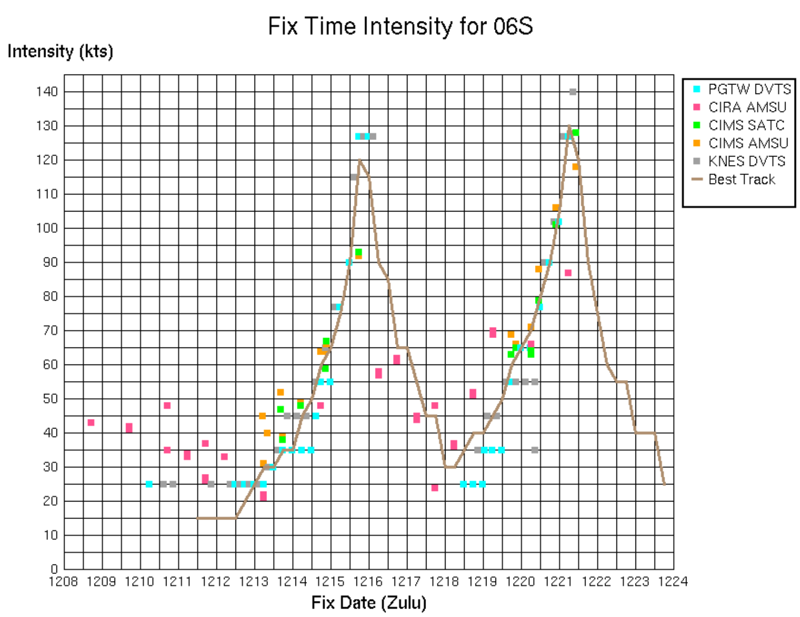




Tropical Cyclone 06S (Laurence)

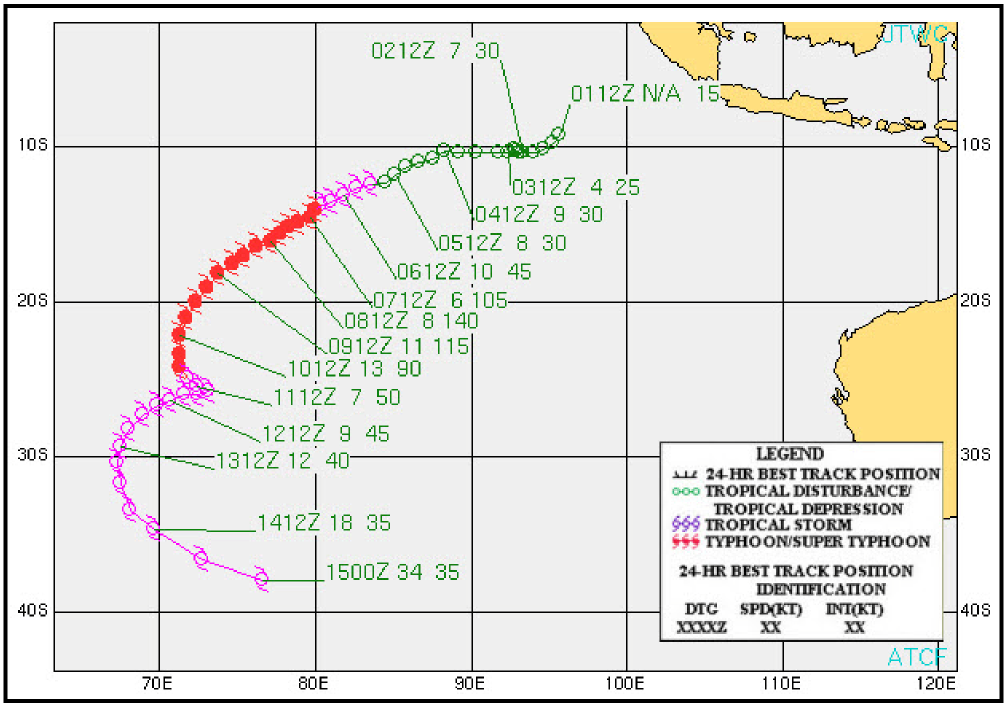
ISSUED POOR:	0600Z 10 Dec 2009
ISSUED FAIR:	1800Z 10 Dec 2009
FIRST TCFA:	2200Z 11 Dec 2009
FIRST WARNING:	0600Z 13 Dec 2009
LAST WARNING:	1200Z 21 Dec 2009
MAX INTENSITY:	130 Kts
NUMBER OF WARNINGS:	15

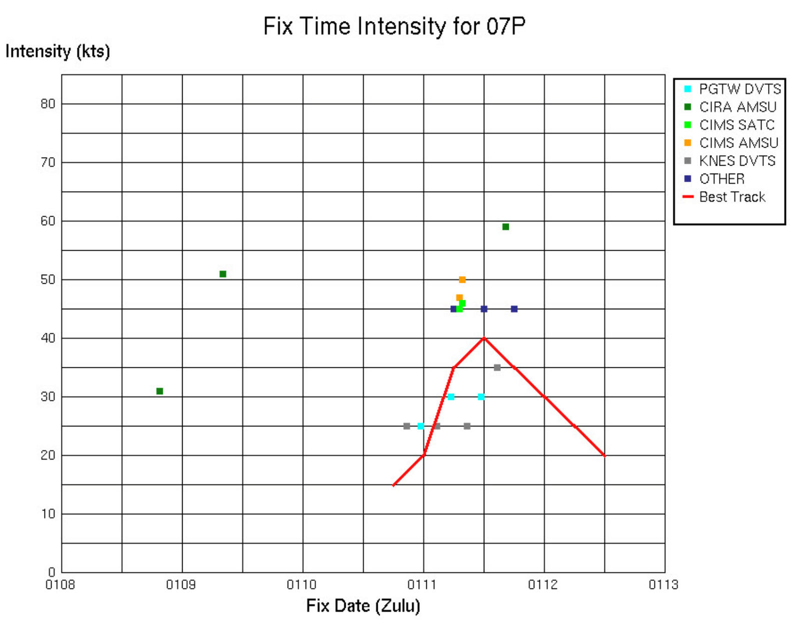




Tropical Cyclone 07S (Edzani)

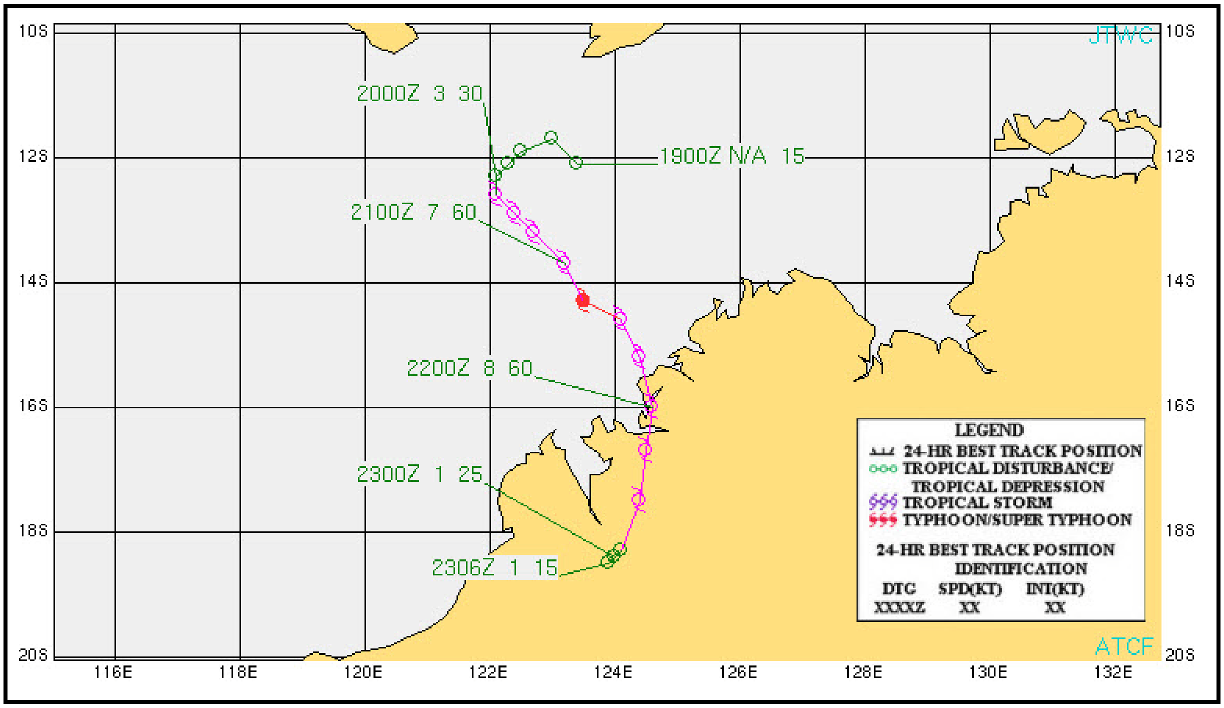
ISSUED POOR:	0230Z 04 Jan 2010
ISSUED FAIR:	1800Z 04 Jan 2010
FIRST TCFA:	0130Z 05 Jan 2010
FIRST WARNING:	0000Z 06 Jan 2010
LAST WARNING:	1800Z 14 Jan 2010
MAX INTENSITY:	140 Kts
NUMBER OF WARNINGS:	18

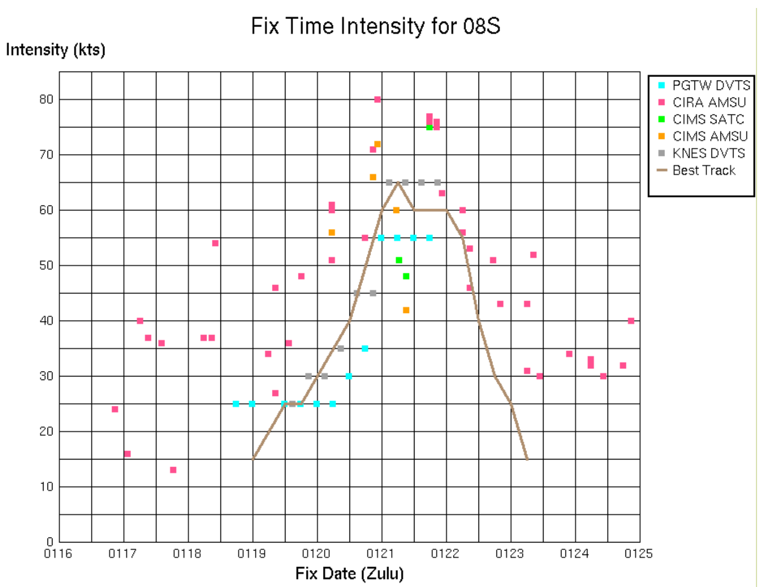




Tropical Cyclone 08S (Magda)

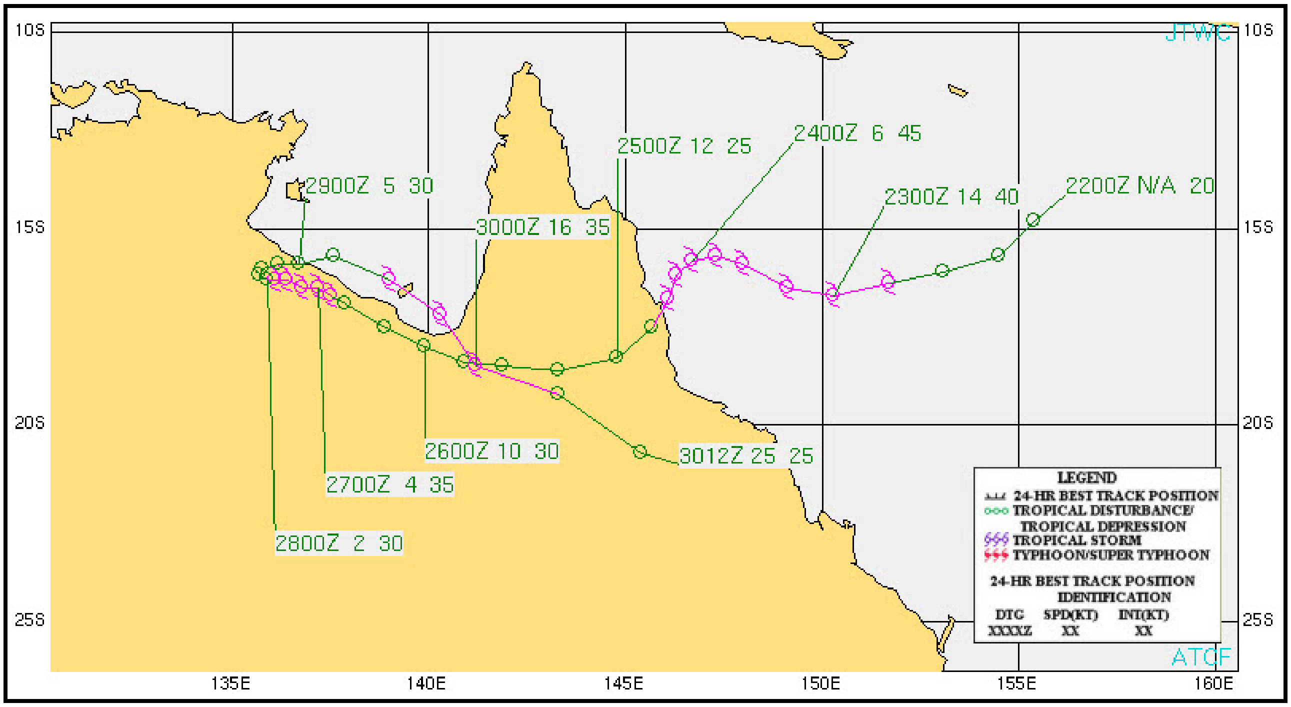
ISSUED POOR:	1230Z 19 Jan 2010
ISSUED FAIR:	N/A
FIRST TCFA:	2130Z 19 Jan 2010
FIRST WARNING:	1800Z 20 Jan 2010
LAST WARNING:	1800Z 22 Jan 2010
MAX INTENSITY:	65 Kts
NUMBER OF WARNINGS:	5

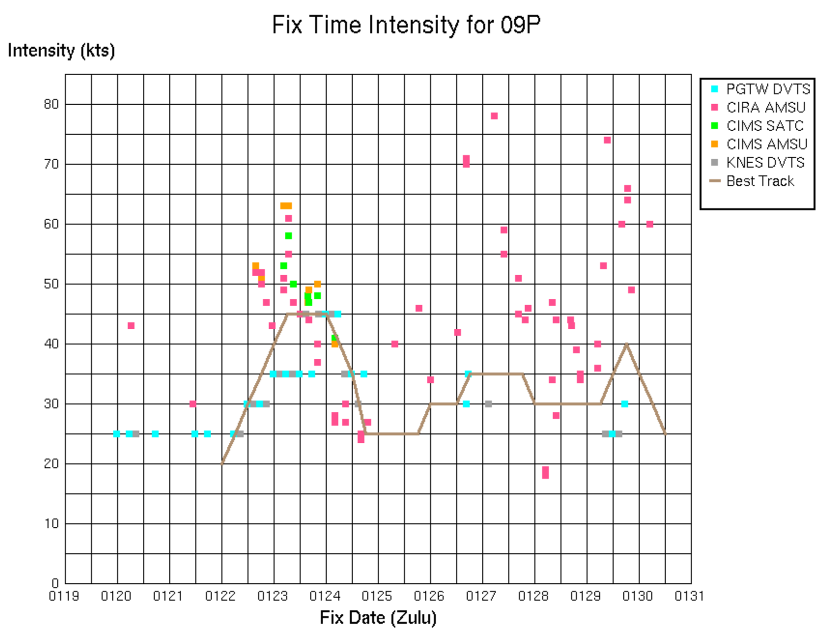




Tropical Cyclone 09P (Olga)

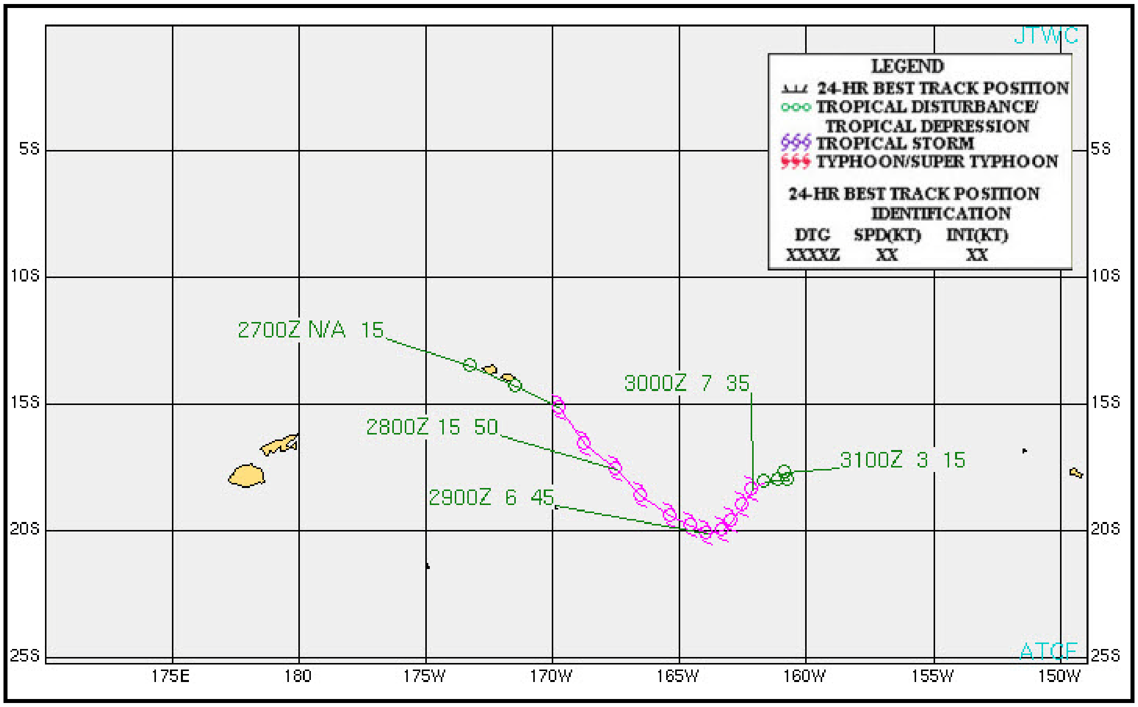
ISSUED POOR:	0600Z 22 Jan 2010
ISSUED FAIR:	N/A
FIRST TCFA:	2030Z 22 Jan 2010
FIRST WARNING:	0000Z 23 Jan 2010
LAST WARNING:	0000Z 30 Jan 2010
MAX INTENSITY:	45 Kts
NUMBER OF WARNINGS:	10

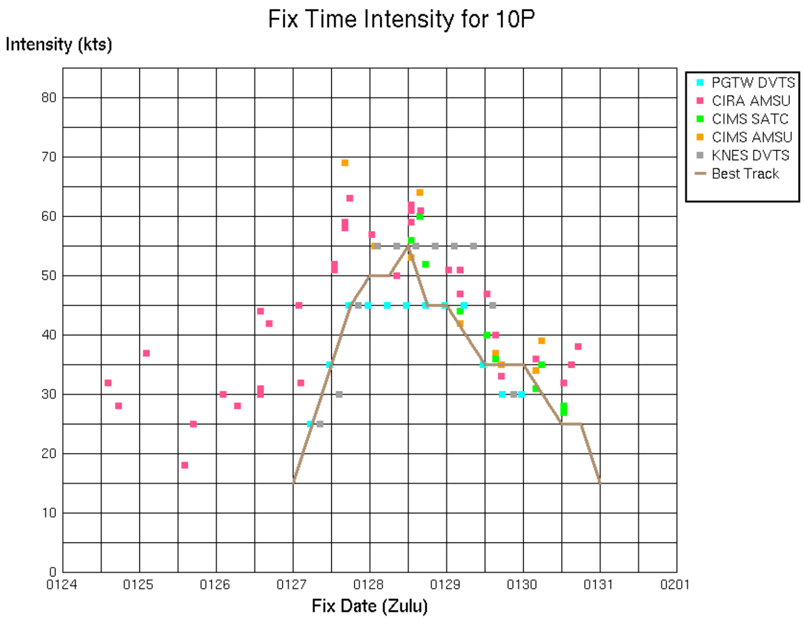




Tropical Cyclone 10P (Nisha)

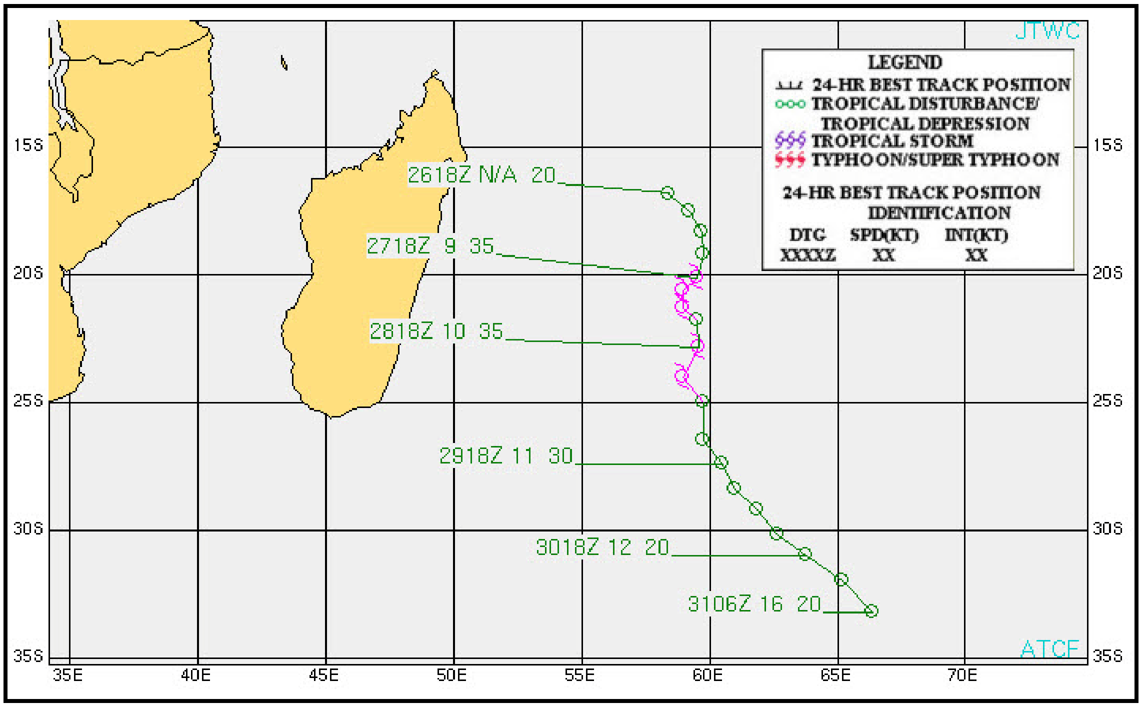
ISSUED POOR:	N/A
ISSUED FAIR:	0600Z 27 Jan 2010
FIRST TCFA:	N/A
FIRST WARNING:	1200Z 27 Jan 2010
LAST WARNING:	0000Z 30 Jan 2010
MAX INTENSITY:	55 Kts
NUMBER OF WARNINGS:	6

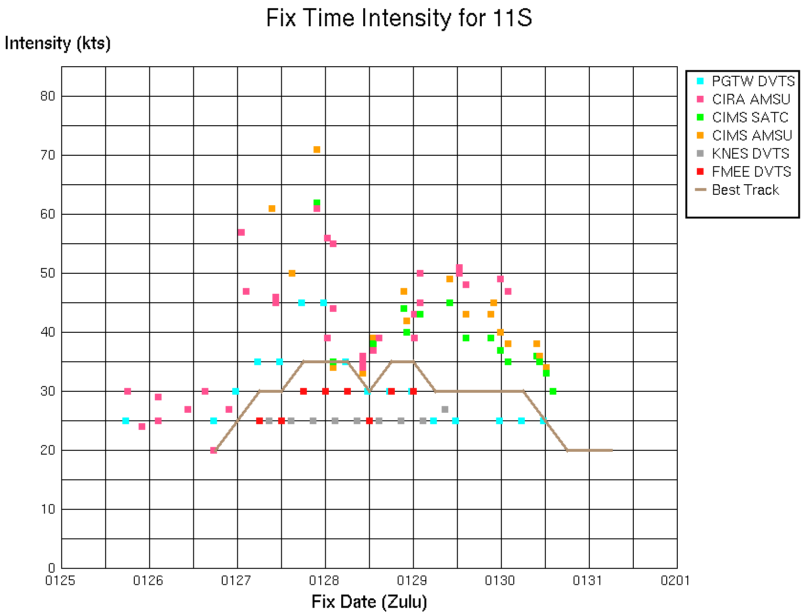




Tropical Cyclone 11S (No Name)

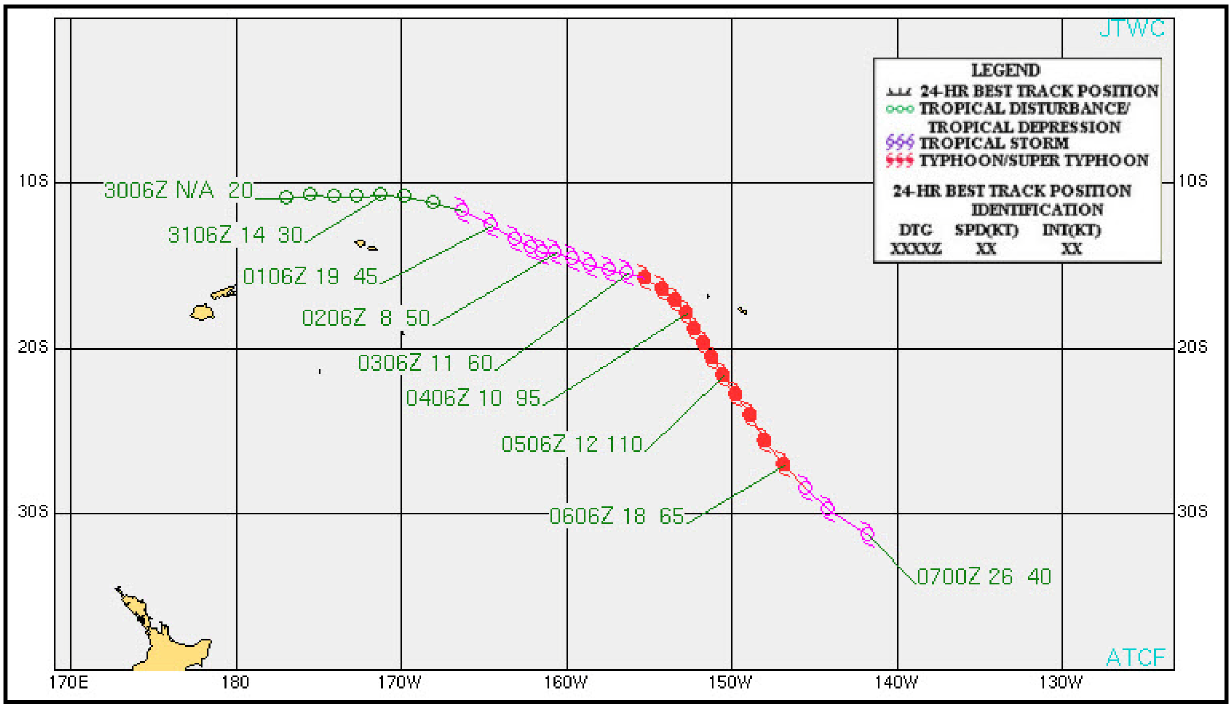
ISSUED POOR:	0200Z 26 Jan 2010
ISSUED FAIR:	0100Z 27 Jan 2010
FIRST TCFA:	0930Z 27 Jan 2010
FIRST WARNING:	1800Z 27 Jan 2010
LAST WARNING:	0600Z 30 Jan 2010
MAX INTENSITY:	35 Kts
NUMBER OF WARNINGS:	6

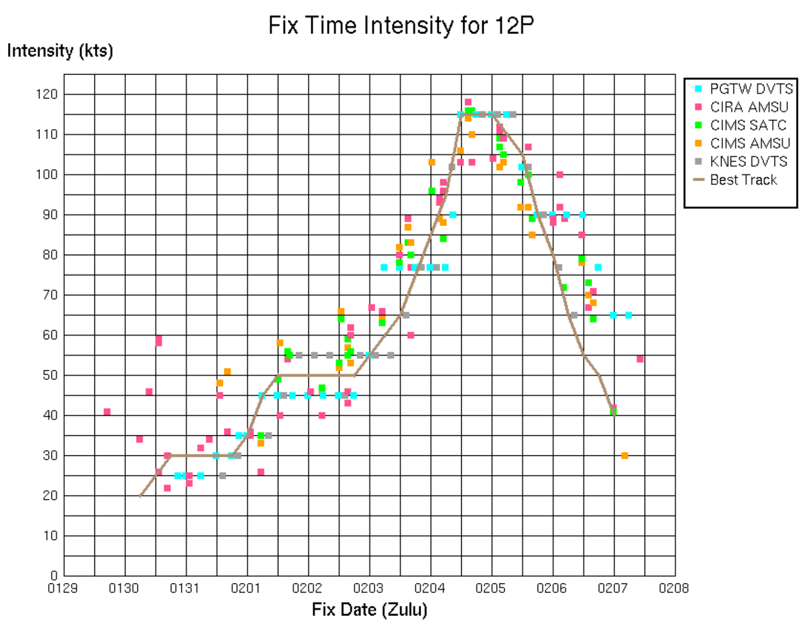




Tropical Cyclone 12P (Oli)

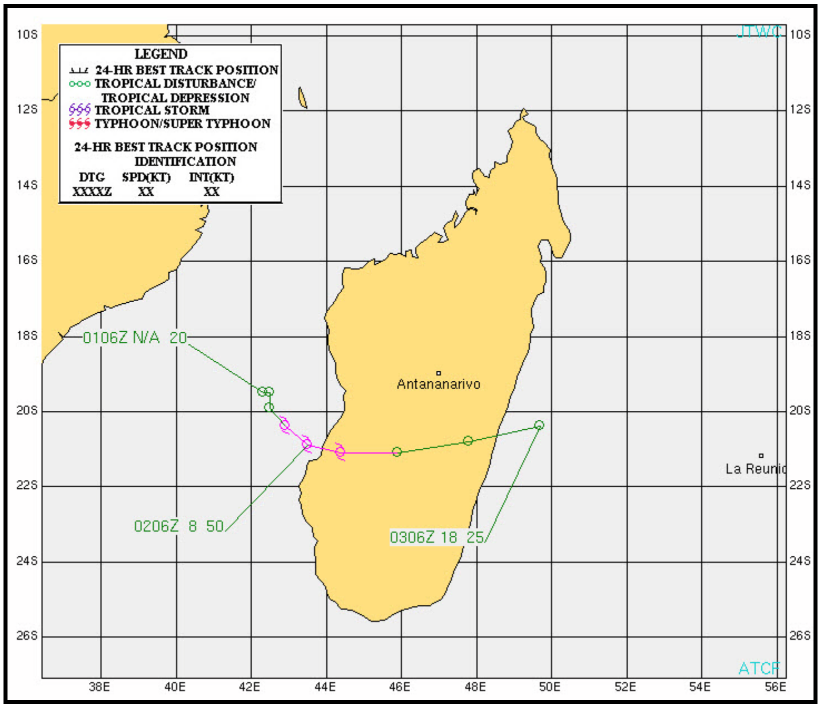
ISSUED POOR:	1200Z 30 Jan 2010
ISSUED FAIR:	2030Z 30 Jan 2010
FIRST TCFA:	1500Z 31 Jan 2010
FIRST WARNING:	0000Z 01 Feb 2010
LAST WARNING:	1200Z 06 Feb 2010
MAX INTENSITY:	115 Kts
NUMBER OF WARNINGS:	12

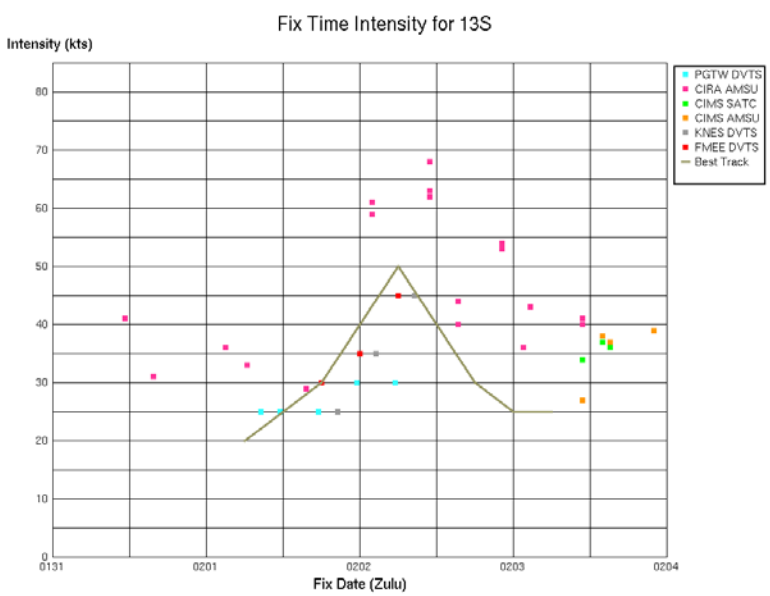




Tropical Cyclone 13S (Fami)

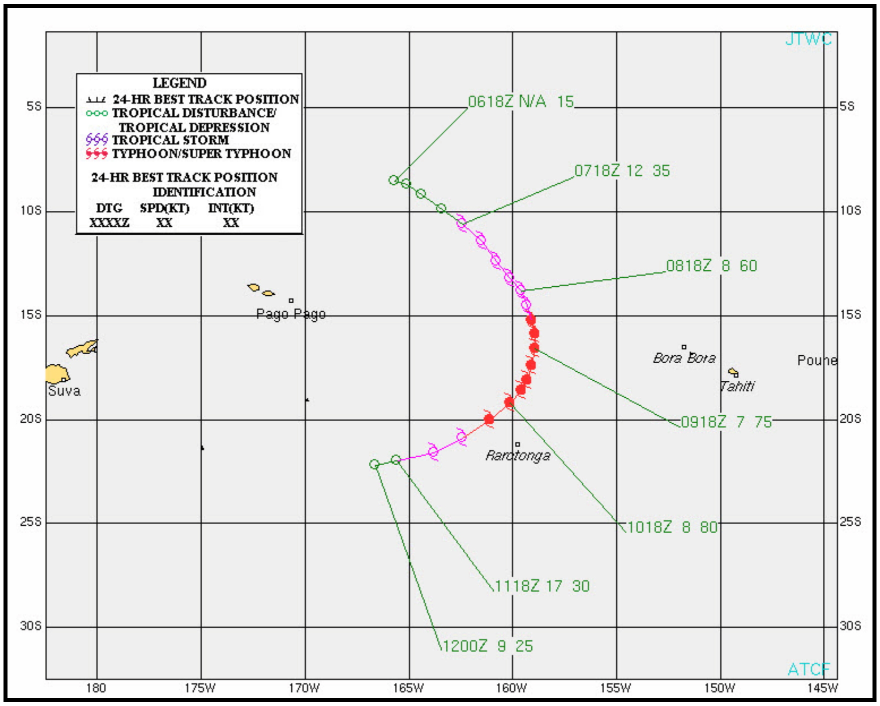
ISSUED POOR:	1000Z 01 Feb 2010
ISSUED FAIR:	2200Z 01 Feb 2010
FIRST TCFA:	0230Z 02 Feb 2010
FIRST WARNING:	0600Z 02 Feb 2010
LAST WARNING:	1800Z 02 Feb 2010
MAX INTENSITY:	50 Kts
NUMBER OF WARNINGS:	2

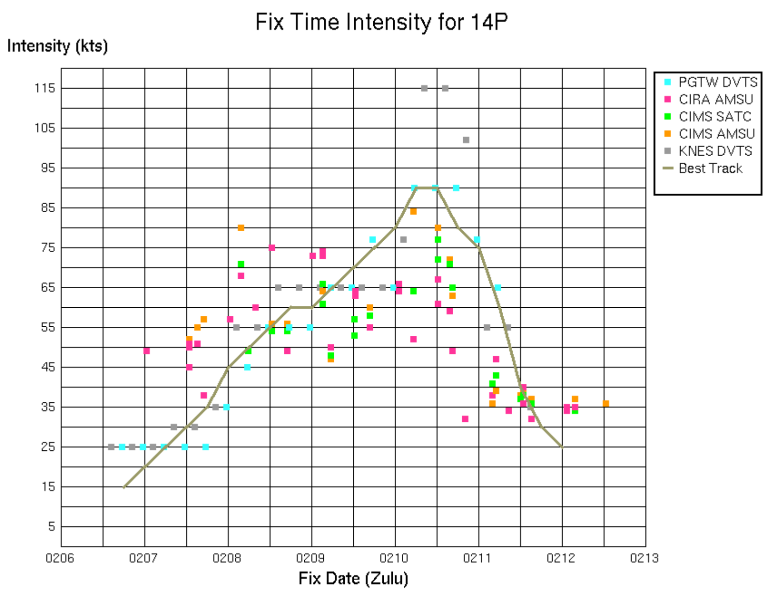




Tropical Cyclone 14P (Pat)

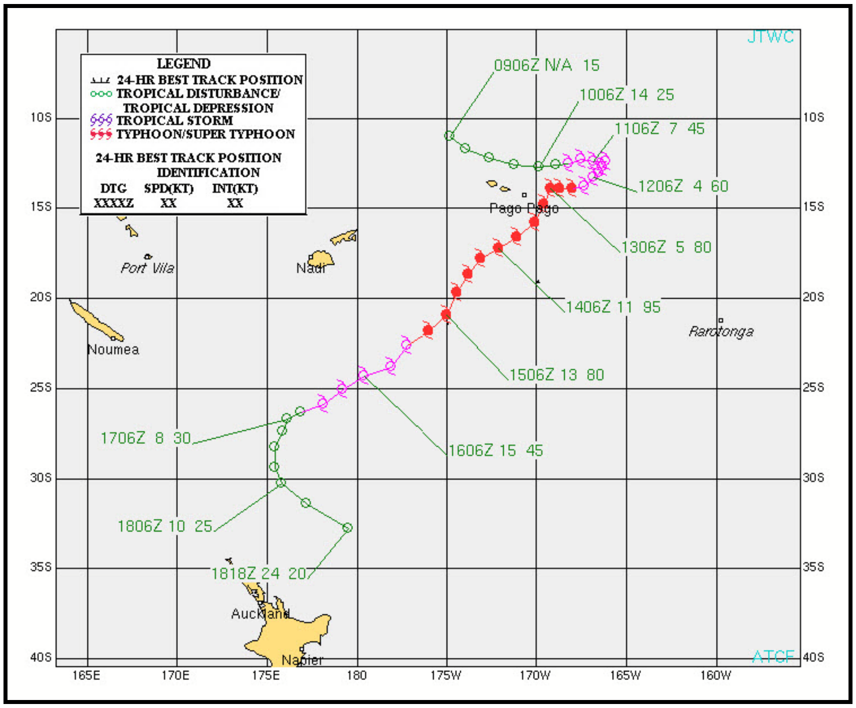
ISSUED POOR:	N/A
ISSUED FAIR:	2000Z 06 Feb 2010
FIRST TCFA:	0730Z 07 Feb 2010
FIRST WARNING:	1800Z 07 Feb 2010
LAST WARNING:	1800Z 11Feb 2010
MAX INTENSITY:	90 Kts
NUMBER OF WARNINGS:	8

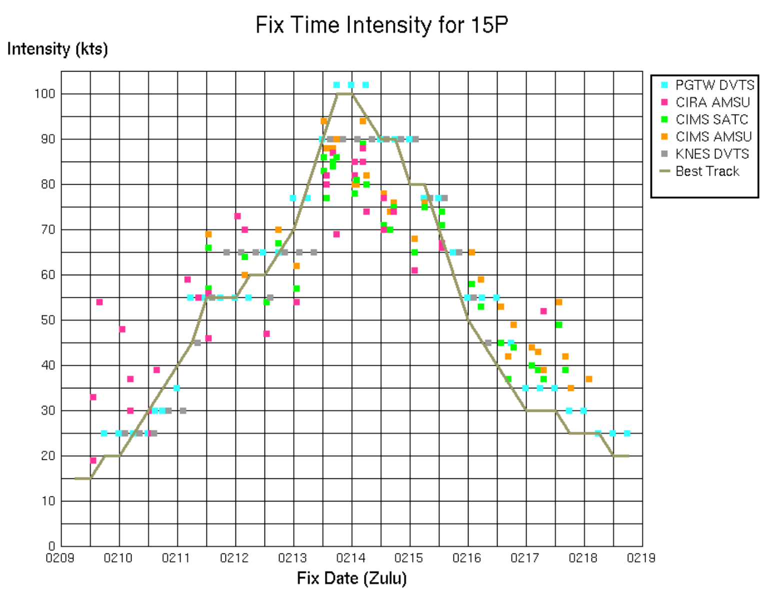




Tropical Cyclone 15P (Rene)

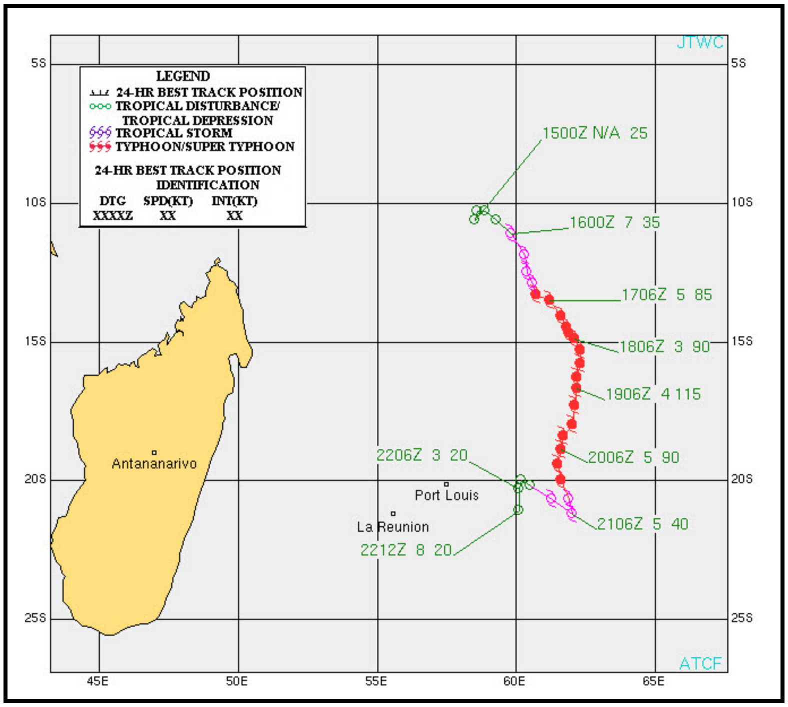
ISSUED POOR:	2130Z 09 Feb 2010
ISSUED FAIR:	N/A
FIRST TCFA:	0530Z 10 Feb 2010
FIRST WARNING:	0000Z 11 Feb 2010
LAST WARNING:	1800Z 16 Feb 2010
MAX INTENSITY:	100 Kts
NUMBER OF WARNINGS:	17

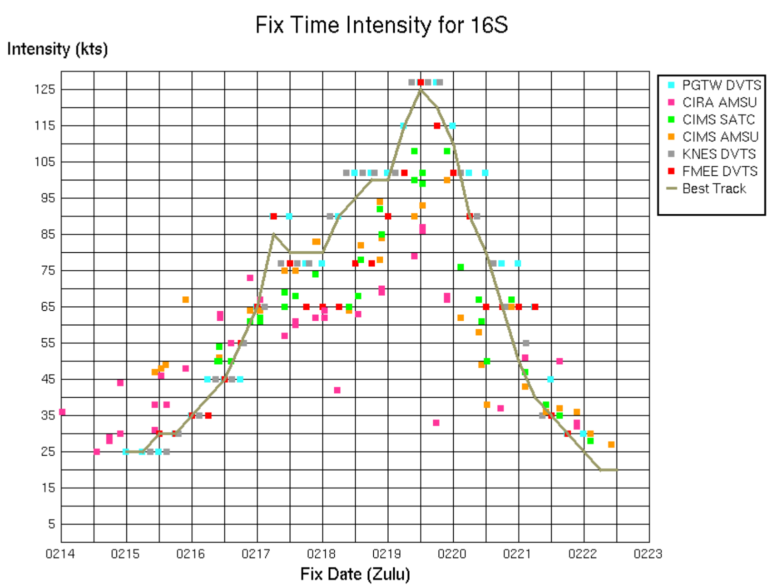




Tropical Cyclone 16S (Gelane)

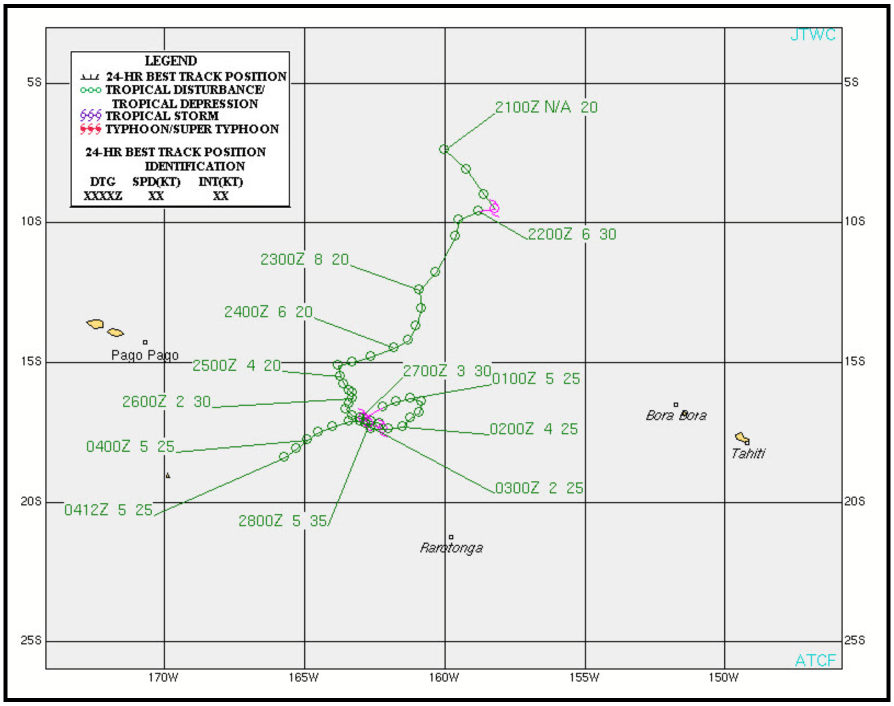
ISSUED POOR:	0030Z 15 Feb 2010
ISSUED FAIR:	0530Z 15 Feb 2010
FIRST TCFA:	2200Z 15 Feb 2010
FIRST WARNING:	0000Z 16 Feb 2010
LAST WARNING:	1800Z 21 Feb 2010
MAX INTENSITY:	125 Kts
NUMBER OF WARNINGS:	18

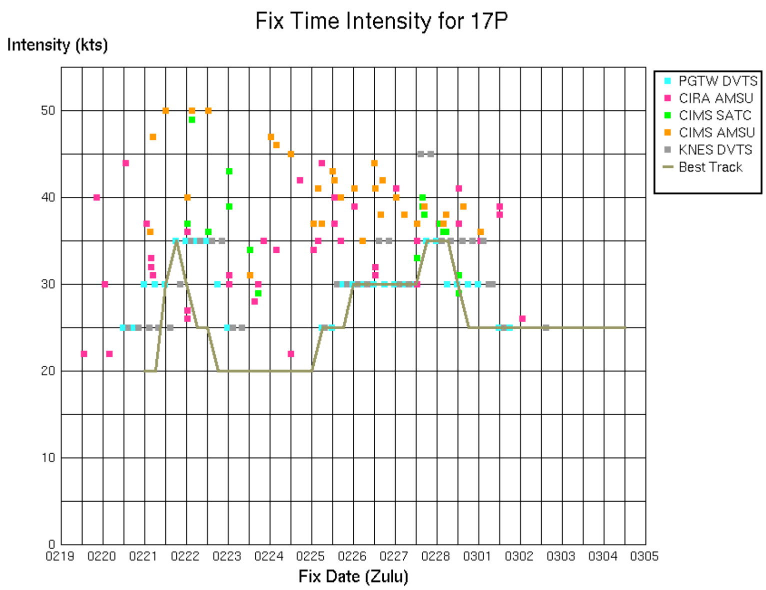




Tropical Cyclone 17P (Sarah)

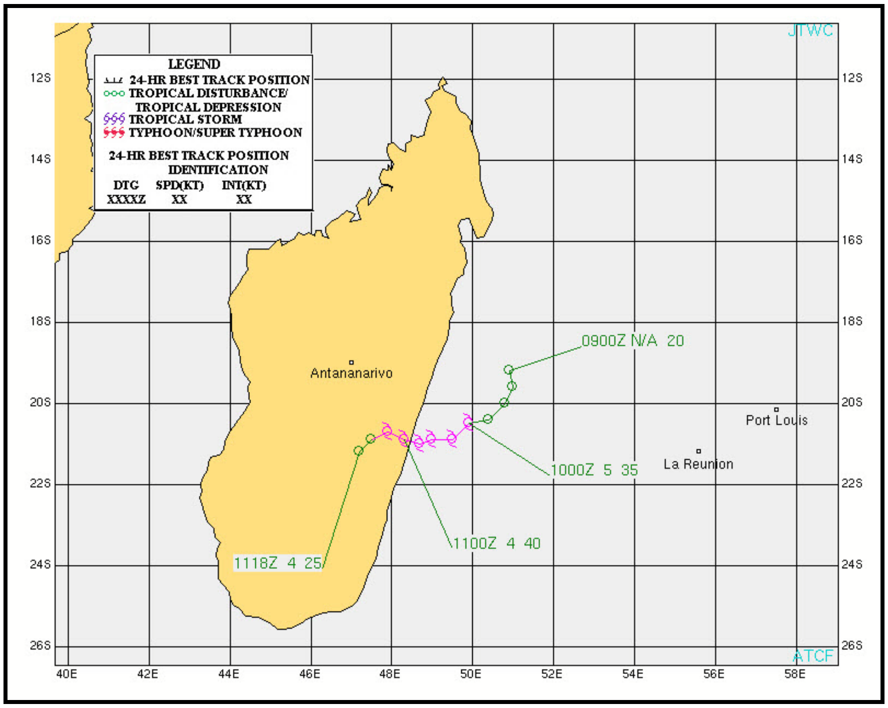
ISSUED POOR:	0100Z 20 Feb 2010
ISSUED FAIR:	0600Z 20 Feb 2010
FIRST TCFA:	0930Z 21 Feb 2010
FIRST WARNING:	1800Z 21 Feb 2010
LAST WARNING:	1800Z 22 Feb 2010
MAX INTENSITY:	35 Kts
NUMBER OF WARNINGS:	3

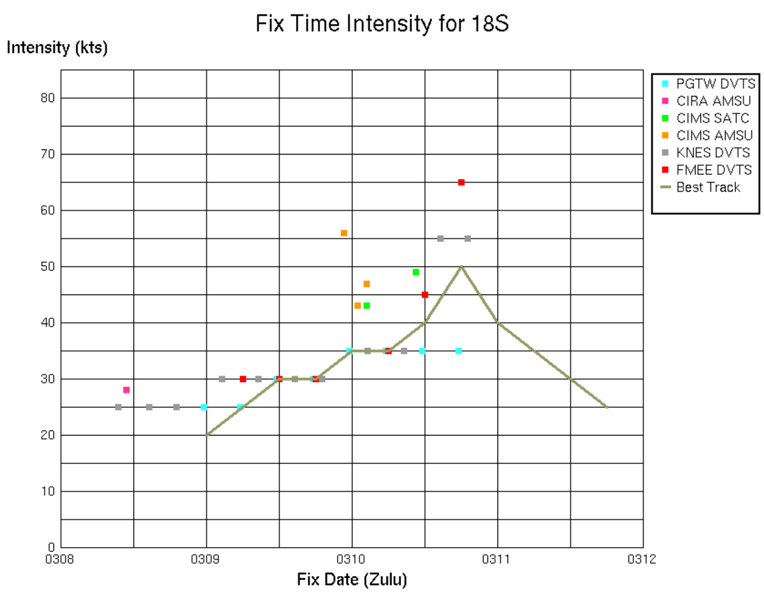




Tropical Cyclone 18S (Hubert)

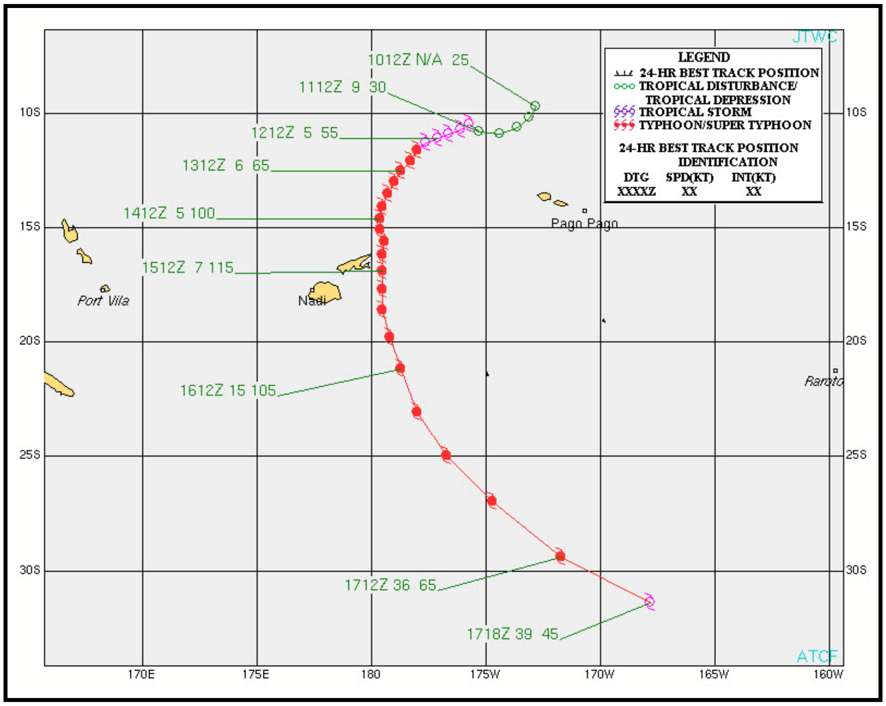
ISSUED POOR:	1030Z 18 Mar 2010
ISSUED FAIR:	N/A
FIRST TCFA:	1400Z 19 Mar 2010
FIRST WARNING:	0000Z 10 Mar 2010
LAST WARNING:	1200Z 10 Mar 2010
MAX INTENSITY:	50 Kts
NUMBER OF WARNINGS:	2

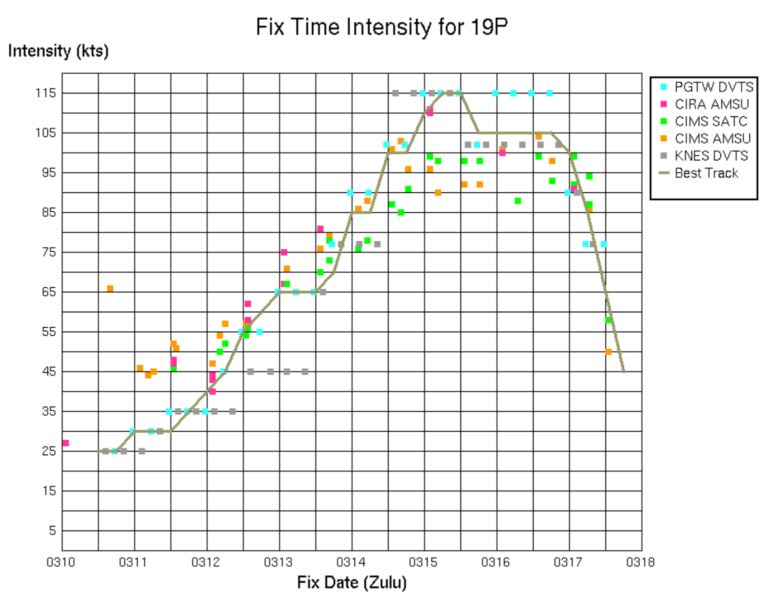




Tropical Cyclone 19P (Tomas)

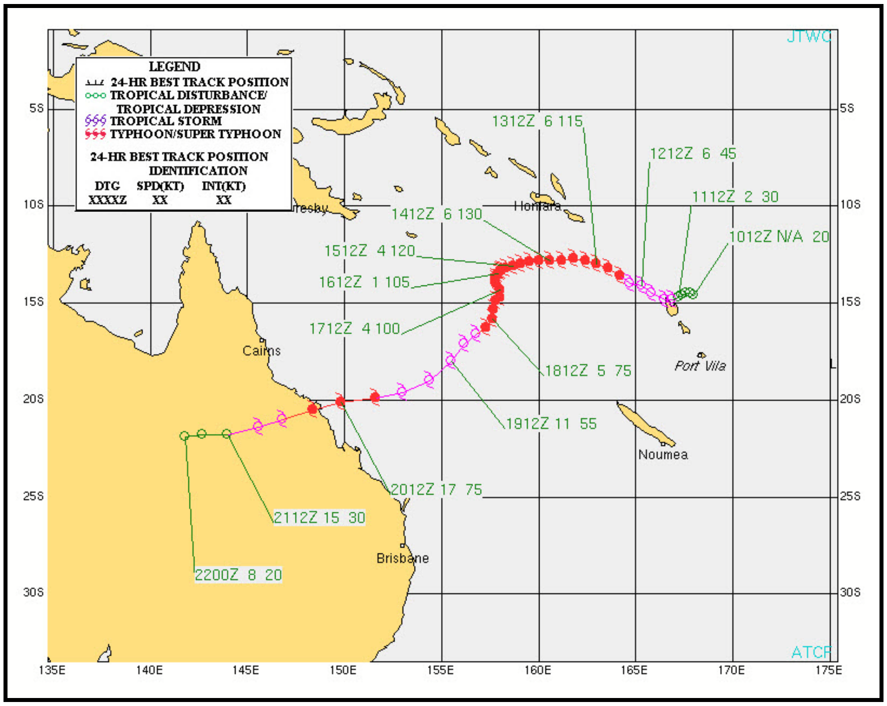
ISSUED POOR:	N/A
ISSUED FAIR:	1630Z 10 Mar 2010
FIRST TCFA:	2230Z 10 Mar 2010
FIRST WARNING:	1200Z 11 Mar 2010
LAST WARNING:	0600Z 17 Mar 2010
MAX INTENSITY:	115 Kts
NUMBER OF WARNINGS:	13

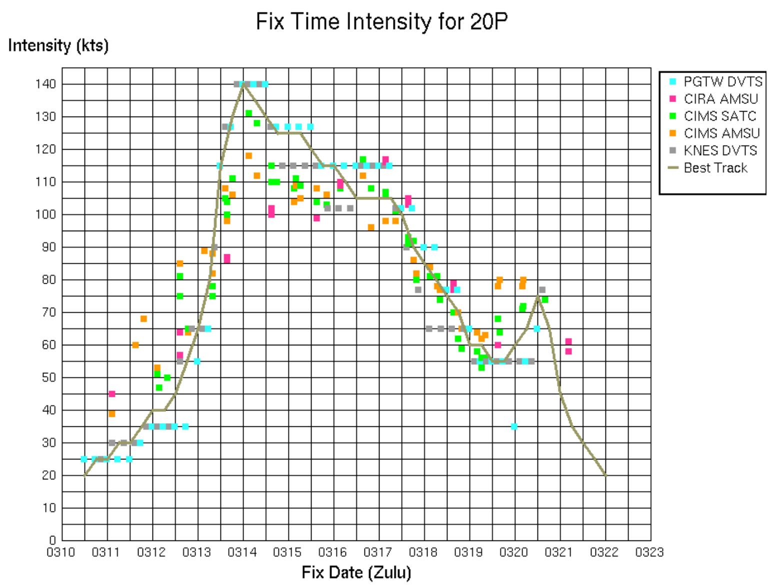




Tropical Cyclone 20P (Ului)

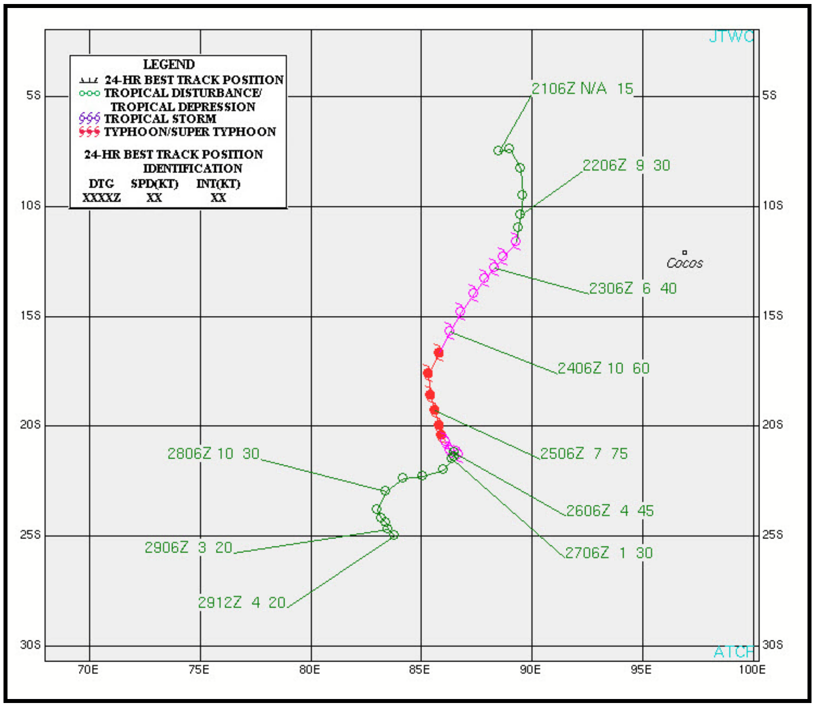
ISSUED POOR:	N/A
ISSUED FAIR:	1630Z 10 Mar 2010
FIRST TCFA:	2200Z 10 Mar 2010
FIRST WARNING:	1800Z 11 Mar 2010
LAST WARNING:	1800Z 20 Mar 2010
MAX INTENSITY:	140 Kts
NUMBER OF WARNINGS:	21

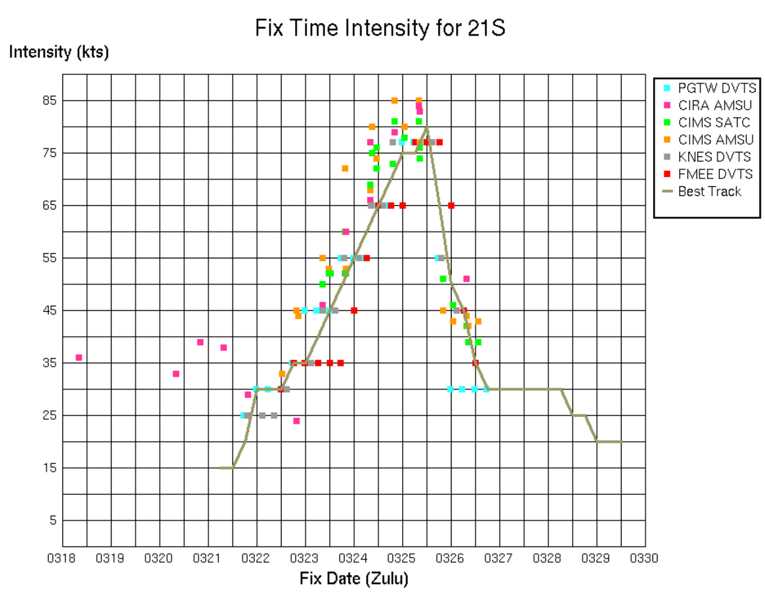




Tropical Cyclone 21S (Imani)

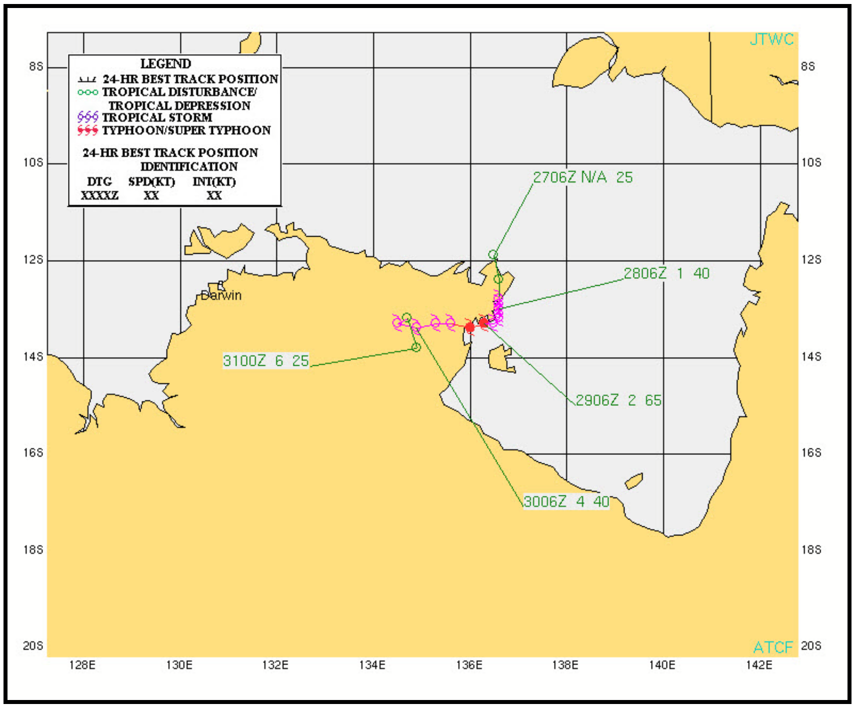
ISSUED POOR:	1800Z 18 Mar 2010
ISSUED FAIR:	1800Z 21 Mar 2010
FIRST TCFA:	0230Z 22 Mar 2010
FIRST WARNING:	1800Z 22 Mar 2010
LAST WARNING:	1800Z 26 Mar 2010
MAX INTENSITY:	80 Kts
NUMBER OF WARNINGS:	9

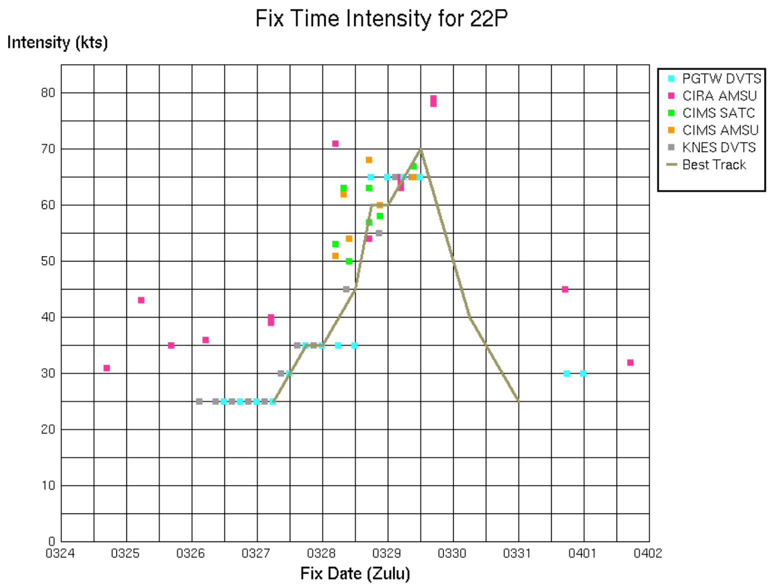




Tropical Cyclone 22P (Paul)

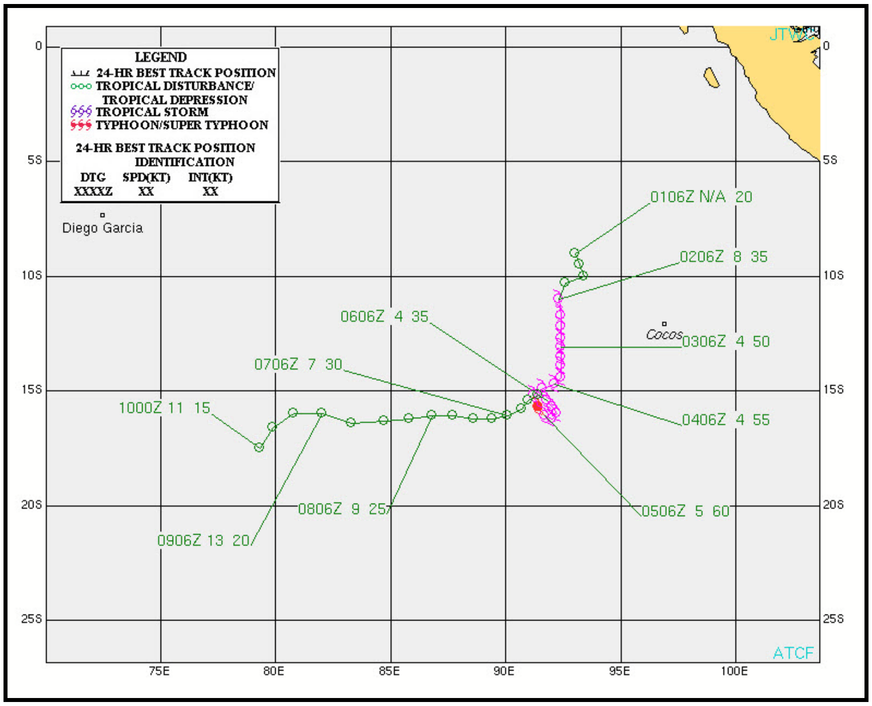
ISSUED POOR:	1800Z 26 Mar 2010
ISSUED FAIR:	2200Z 26 Mar 2010
FIRST TCFA:	1700Z 27 Mar 2010
FIRST WARNING:	1800Z 27 Mar 2009
LAST WARNING:	0600Z 30 Mar 2009
MAX INTENSITY:	70 Kts
NUMBER OF WARNINGS:	6

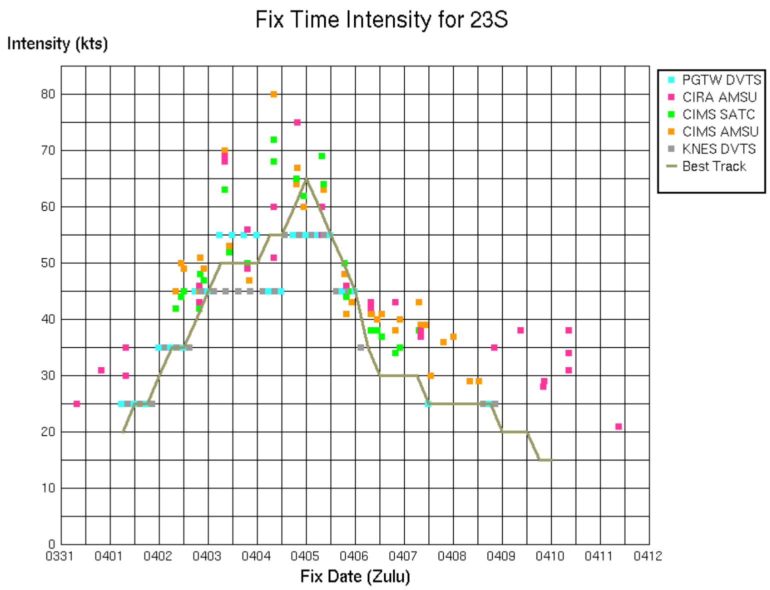




Tropical Cyclone 23S (Robyn)

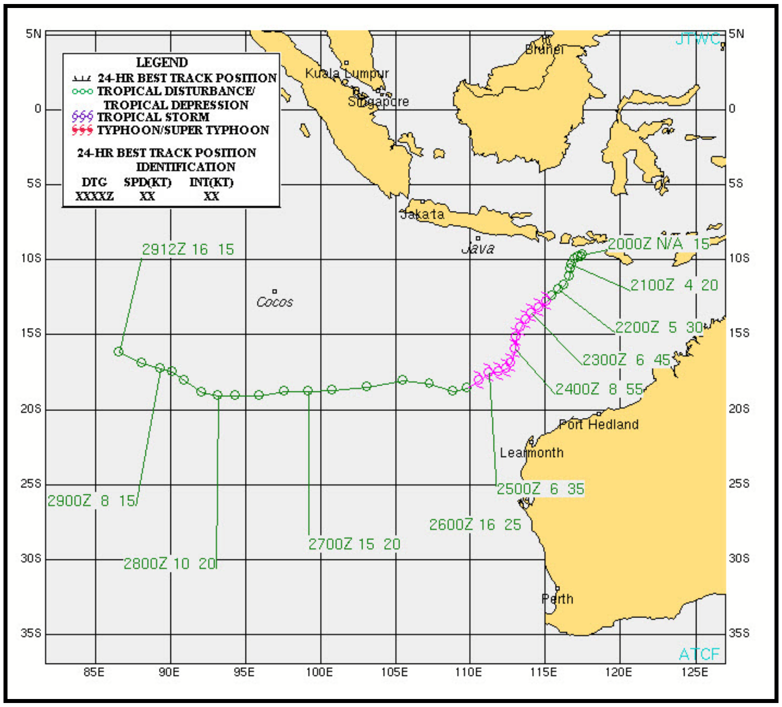
ISSUED POOR:	0700Z 01 Apr 2010
ISSUED FAIR:	2230Z 01 Apr 2010
FIRST TCFA:	0130Z 02 Apr 2010
FIRST WARNING:	0600Z 02 Apr 2010
LAST WARNING:	0600Z 06 Apr 2010
MAX INTENSITY:	65 Kts
NUMBER OF WARNINGS:	9

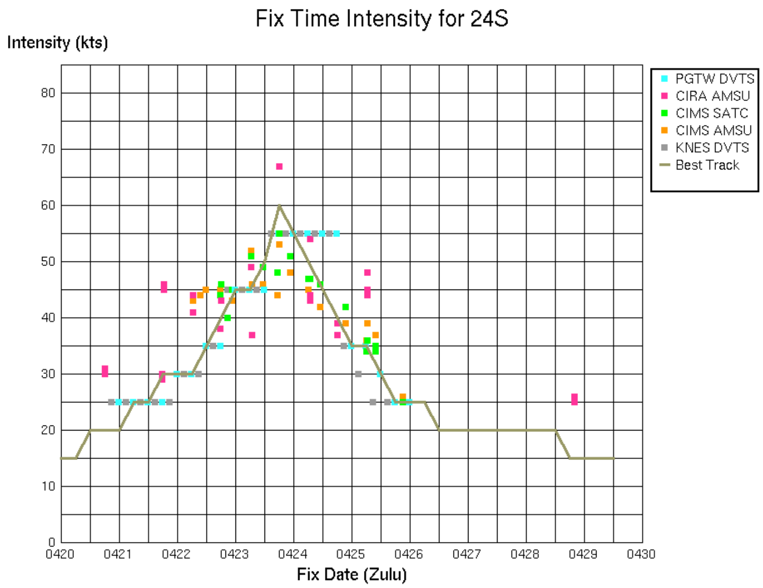




Tropical Cyclone 24S (Sean)

ISSUED POOR: 1230Z 20 Apr 2010
ISSUED FAIR: 2200Z 20 Apr 2010
FIRST TCFA: 1000Z 21 Apr 2010
FIRST WARNING: 1200Z 22 Apr 2010
LAST WARNING: 0000Z 25 Apr 2010
MAX INTENSITY: 60 Kts
NUMBER OF WARNINGS: 7





Chapter 4 Tropical Cyclone Fix Data

Section 1 Background

Weather satellite data continued to be the mainstay for the TC reconnaissance mission at the JTWC. The year brought below average numbers of storms in all three ocean basins, the West Pacific, South Pacific, and Southern Indian Ocean. Satellite analysts exploited a wide variety of conventional and microwave satellite data to produce 7,770 position and intensity estimates. A total of 4,219 fixes were done using microwave imagery, amounting to over half of the total number of fixes. The USAF primary weather satellite direct readout system, Mark IVB, and the USN FMQ-17 continued to be invaluable tools in the TC reconnaissance mission. The following tables depict the fixes produced by our satellite analysts, broken down by basin and storm numbers. Following the final numbered storm for each section, is a value representing the number of fixes for invests considered as Did Not Develop (DND) areas. DNDs are areas that were fixed on but did not reach warning criteria.

Section 2 Fix summary by basin

Table 4-1

WESTERN NORTH PACIFIC OCEAN FIX SUMMARY FOR 2010

Tropical Cyclone		Visible/Infrared	Microwave	Total
01W		21	14	35
02W	Omais	72	88	160
03W	Conson	60	87	147
04W	Chanthu	49	70	119
05W	Dianmu	49	68	117
06W	Mindulle	40	74	114
07W	Lionrock	61	86	147
08W	Kompasu	53	80	133
09W	Namtheun	21	26	47
10W	Malou	58	82	140
11W	Meranti	42	48	90
12W	Fanapi	60	84	144
13W	Malakas	53	77	130
14W		13	7	20
15W	Megi	98	131	229
16W	Chaba	84	120	204
17W		51	70	121
18W		29	23	52
19W		23	27	50
DND		237	191	428
Totals		**1174**	**1453**	**2627**
Percentage of Total		**44.69%**	**55.31%**	

Table 4-2 NORTHERN INDIAN OCEAN FIX SUMMARY FOR 2010				
Tropical Cyclone		Visible/Infrared	Microwave	Total
01B	Laila	54	57	111
02A	Bandu	70	66	136
03A	Phet	66	84	150
04B	Giri	27	36	63
05B	Jal	54	67	121
DND		47	59	106
Totals		**318**	**369**	**687**
Percentage of Total		**46.29%**	**53.71%**	

Table 4-3 SOUTH PACIFIC & SOUTH INDIAN OCEAN FIX SUMMARY FOR 2010				
Tropical Cyclone		Visible/Infrared	Microwave	Total
01S	Anja	41	76	117
02S	Bongani	37	45	82
03S	Cleo	102	166	268
04P	Mick	41	40	81
05S	David	178	273	451
06S	Laurence	110	73	183
07S	Edzani	112	170	282
08S	Magda	44	24	68
09P	Olga	63	21	84
10P	Nisha	27	36	63
11S		37	56	93
12P	Oli	60	75	135
13S	Fami	14	5	19
14P	Pat	45	67	112
15P	Rene	75	115	190
16S	Gelane	68	89	157
17P	Sarah	85	108	193
18S	Hubert	46	75	121
19P	Tomas	57	96	153
20P	Ului	96	146	242
21S	Imani	64	84	148
22P	Paul	53	43	96
23S	Robyn	86	115	201
24S	Sean	64	114	178
DND		454	285	739
Totals		**2059**	**2397**	**4456**
Percentage of Total		**46.21%**	**53.79%**	

Chapter 5 Techniques Development Summary

Section 1 Background

The JTWC Techniques Development (Tech Dev) team's mission is to facilitate operations and improve TC analyses and forecasts through scientific study, techniques development, information technology exploitation, data evaluation, and process improvement. This section of the 2010 ATCR provides a small sampling of scientific and operational resource projects conducted by the JTWC Tech Dev team during 2010 and a look at ongoing and future work.

Section 2 2010 projects

Impact of Typhoons on the Ocean in the Pacific (ITOP): JTWC Tech Dev provided satellite analysts and forecasters the requisite tools to successfully interpret and apply additional real-time, in-situ data collected during the study during the 2010 Impact of Typhoons on the Ocean in the Pacific (ITOP) multi-national field study. Tech Dev further coordinated communication between JTWC and the ITOP research team during the two month long project and directly participated by flying missions onboard the WC-130J during reconnaissance flights.

Global Tropics Hazards participation: In August, JTWC Tech Dev began participating in the Climate Prediction Center's weekly Global Tropics Hazards (GTH) Assessment. The subjective GTH Assessment provides US Government interests a two week outlook of potential tropical cyclone formation areas across the global tropics. This is the first-ever mid-range TC prediction capability to support USPACOM.

Human factors evaluation: In October, JTWC Tech Dev facilitated a site visit by Dr. Alex Kirlik from the University of Illinois and Dr. Eva Regnier from the Naval Postgraduate School. These researchers are evaluating human and technological factors that influence analysis and forecasting processes at JTWC. Recommendations from their final report will focus future efforts to increase operational efficiency.

Subjective and automated intensity fix evaluation: JTWC Tech Dev completed a comprehensive review of subjective and automated tropical cyclone intensity estimates and presented recommendations for operational application of these data to the organization's forecasters. Results from the study influenced a recent decision by NOAA/NESDIS to continue global subjective fixing. Conclusions from this study will also aid upcoming efforts to improve the Automated Tropical Forecast System (ATCF) objective best track technique.

Google Earth Meteorological INformation Interface (GEMINI): JTWC Tech Dev continued development of GEMINI, a scalable meteorological data display platform for tropical cyclone analysis and forecasting using the Google Earth software application. The objective of GEMINI is to improve speed and ease of weather data retrieval and to enhance multisource data comparison. Efforts to improve GEMINI in 2010 included expanding observational data display capabilities and coordinating generation of large-scale microwave satellite data composites with the Naval Research Laboratory.

Data flow and troubleshooting guide: Tech Dev compiled a comprehensive, interactive guide to the complex processes that provide satellite imagery, numerical model fields, tropical cyclone

vortex trackers, and other critical data to JTWC. The guide details troubleshooting procedures for each data transfer process, including steps to manually retrieve data whenever possible.

Contingency of Operations Plan (COOP): In concert with the JTWC Operations Department, Tech Dev established new off-site operational backup procedures, testing connections and software and writing standard operating procedures. The JTWC COOP at the 17th Operational Weather Squadron includes fully capable ATCF and Mark IVB workstations. The COOP was exercised during a 2-day scheduled power outage at JTWCs primary location.

Section 3 Ongoing and future projects

Classifying TC genesis probability: JTWC Tech Dev is developing a standardized process to classify tropical cyclone genesis probability as low, medium, and high based on the existence of single, primary development indicators or combinations of secondary indicators. JTWC plans to implement the new classification system on 1 June 2011. Additionally, Tech Dev is planning to evaluate Office of Naval Research (ONR)-funded TC genesis prediction methods under development at the University of Arizona, Naval Research Laboratory and University of Hawaii.

Ocean surface vector wind (OSVW) study: Tech Dev coordinated JTWC's involvement in a study commissioned by the Commander Naval Meteorology and Oceanography Command (CNMOC) to document the impacts of ocean surface vector wind (OSVW) data on numerical model forecasts. Satellite analysts at JTWC will re-fix TCs in the western North Pacific from 2009 and Typhoon Duty Officers will provide best tracks and boguses with, and without, the influence of OSVW to study participants. Researchers at the Naval Research Laboratory (NRL) will use this tropical cyclone best track data, specially prepared for the study by JTWC, to reinitialize the numerical forecast models.

Tropical cyclone climatology resources: Tech Dev is using JTWC historical tropical cyclone track and intensity data to construct geographical composites of climatological trends, including tropical cyclone formation and rapid intensification, for internal reference and operational application.

Forecast process checklists: JTWC Tech Dev is developing multiple checklists to guide the forecast process. These checklists will improve continuity of effort and sharpen forecasters' focus on key meteorological features that impact forecasts.

Rapid intensification (RI) prediction methodology: JTWC Tech Dev is evaluating new methods to forecast tropical cyclone RI using statistical intensity guidance and microwave satellite imagery. 2010 efforts included near real-time discussions of RI potential for current tropical cyclones with Ms. Margie Kieper, developer of a promising new RI prediction technique. Tech Dev will continue to evaluate this and other innovative statistical RI prediction techniques in 2011. By testing and applying new forecasting methods, JTWC aims to improve quantitative RI prediction at 12-36 hour lead times.

Chapter 6 Summary of Forecast Verification

Verification of warning position and intensities at 24-, 48-, and 72-hour forecast periods are made against the final best track. The (scalar) track forecast, along-track and cross track errors (illustrated in Figure 6-1) were calculated for each verifying JTWC forecast. These data are included in this chapter. This section summarizes verification data for the 2010 season, and contrasts it with annual verification statistics from previous years.

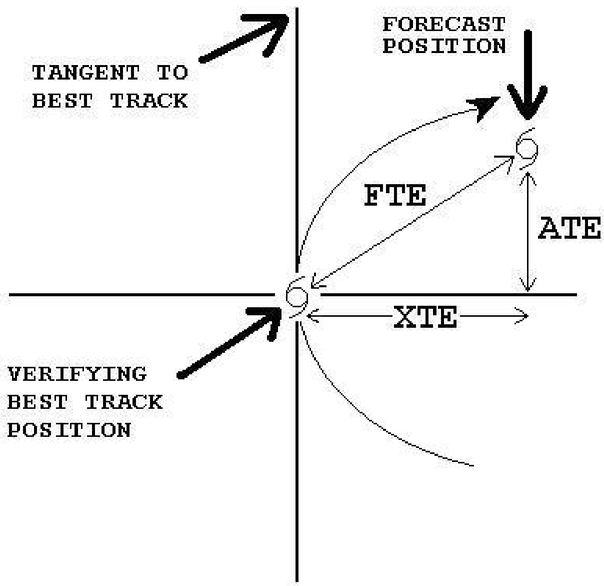


Figure 6-1. Definition of cross-track error (XTE), along track error (ATE), and forecast track error (FTE). In this example, the forecast position is ahead of and to the right of the verifying best track position. Therefore, the XTE is positive (to the right of track) and the ATE is positive (ahead of the best track). Adapted from Tsui and Miller, 1988.

TABLE 6-1
MEAN FORECAST ERRORS (NM) FOR WESTERN NORTH PACIFIC
TROPICAL CYCLONES FROM 1959 - 2010

	24-Hour				48-Hour				72-Hour				96-Hour				120-Hour			
Year (Note)	Cases	TC Mean Error (3)	Cross Track Mean Error (2)	Along Track Mean Error (2)	Cases	TC Mean Error (3)	Cross Track Mean Error (2)	Along Track Mean Error (2)	Cases	TC Mean Error (3)	Cross Track Mean Error (2)	Along Track Mean Error (2)	Cases (1)	TC Mean Error (3)	Cross Track Mean Error (2)	Along Track Mean Error (2)	Cases (1)	TC Mean Error (3)	Cross Track Mean Error (2)	Along Track Mean Error (2)
1959																				
1960																				
1961																				
1962																				
1963																				
1964																				
1965																				
1966																				
1967																				
1968																				
1969																				
1970		104				190				279										
1971		111	64			212	118			317	177									
1972		117	72			245	146			381	210									
1973		108	74			197	134			253	162									
1974		120	78			226	157			348	245									
1975		138	84			288	181			450	290									
1976		117	71			230	132			338	202									
1977		148	83			283	157			407	228									
1978		127	71	87		271	151	194		410	218	296								
1979		124	76	81		226	138	146		316	182	214								
1980		126	76	86		243	147	165		389	230	266								
1981		124	77	80		221	131	146		334	219	206								
1982		113	70	74		238	142	162		342	211	223								
1983		117	73	76		260	164	169		407	263	259								
1984		117	64	84		232	131	163		363	216	238								
1985		117	68	80		231	138	153		367	227	230								
1986		126	70	85		261	151	183		394	227	276								
1987		107	64	71		204	127	134		303	186	198								
1988	353	114	58	85	255	216	103	170	183	315	159	244								
1989	585	120	69	83	458	231	127	162	343	350	177	265								
1990	551	103	60	72	453	203	110	148	334	310	168	225								
1991	673	96	53	69	570	185	97	137	467	287	146	229								
1992	890	107	59	77	739	205	116	143	610	305	172	210								
1993	744	112	63	79	596	212	117	151	469	321	173	226								
1994	920	105	56	76	762	186	105	131	623	258	152	176								
1995	521	123	67	89	409	215	117	159	315	325	167	240								
1996	868	105	56	76	707	178	89	134	604	272	137	203								
1997	905	93	55	76	783	164	87	134	665	245	120	202								
1998	354	124	58	98	257	239	127	178	189	370	201	274								
1999	433	106	59	74	300	176	102	119	191	234	139	155								
2000	605	81	45	57	467	142	80	98	363	209	118	144								
2001	627	73	42	49	512	122	75	78	395	180	110	120	191	289	169	200	139	420	237	299
2002	657	66	37	47	535	116	67	79	421	166	88	120	260	232	107	183	201	292	131	230
2003	602	73	41	52	495	128	68	94	397	186	89	147	238	241	107	197	173	304	126	249
2004	766	70	41	48	646	122	69	84	537	173	95	121	328	206	111	147	242	274	147	195
2005	507	61	38	38	407	102	59	72	316	156	76	120	168	213	106	164	111	263	122	200
2006	512	62	39	40	405	104	61	73	327	151	77	112	206	216	115	155	141	309	167	222
2007	343	61	24	42	260	100	58	69	189	148	83	102	105	189	107	127	63	215	117	155
2008	354	66	38	46	261	120	75	78	192	198	110	140	138	300	163	219	87	447	246	313
2009	498	66	35	47	395	123	65	90	303	183	102	130	227	258	145	183	174	298	158	213
2010	253	59	33	42	192	101	63	65	140	160	95	102	92	223	134	147	54	279	174	179
Avg (1978-2010)	588	98	56	69	472	184	105	129	373	277	156	194	195	237	126	172	139	310	163	226
5yr Avg	392	63	34	43	303	110	64	75	230	168	93	117	154	237	133	166	104	310	172	216

(1) JTWC extended warning period from 72hrs to 120hrs in 2001. 96-hour and 120-hour data is not available prior to 2001.
(2) Cross-track and along-track errors were adopted by the JTWC in 1986. Right angle errors (used prior to 1986) were recomputed as cross-track errors after-the fact to extend the data base.
(3) Mean forecast errors for all warned systems in Northwest Pacific.

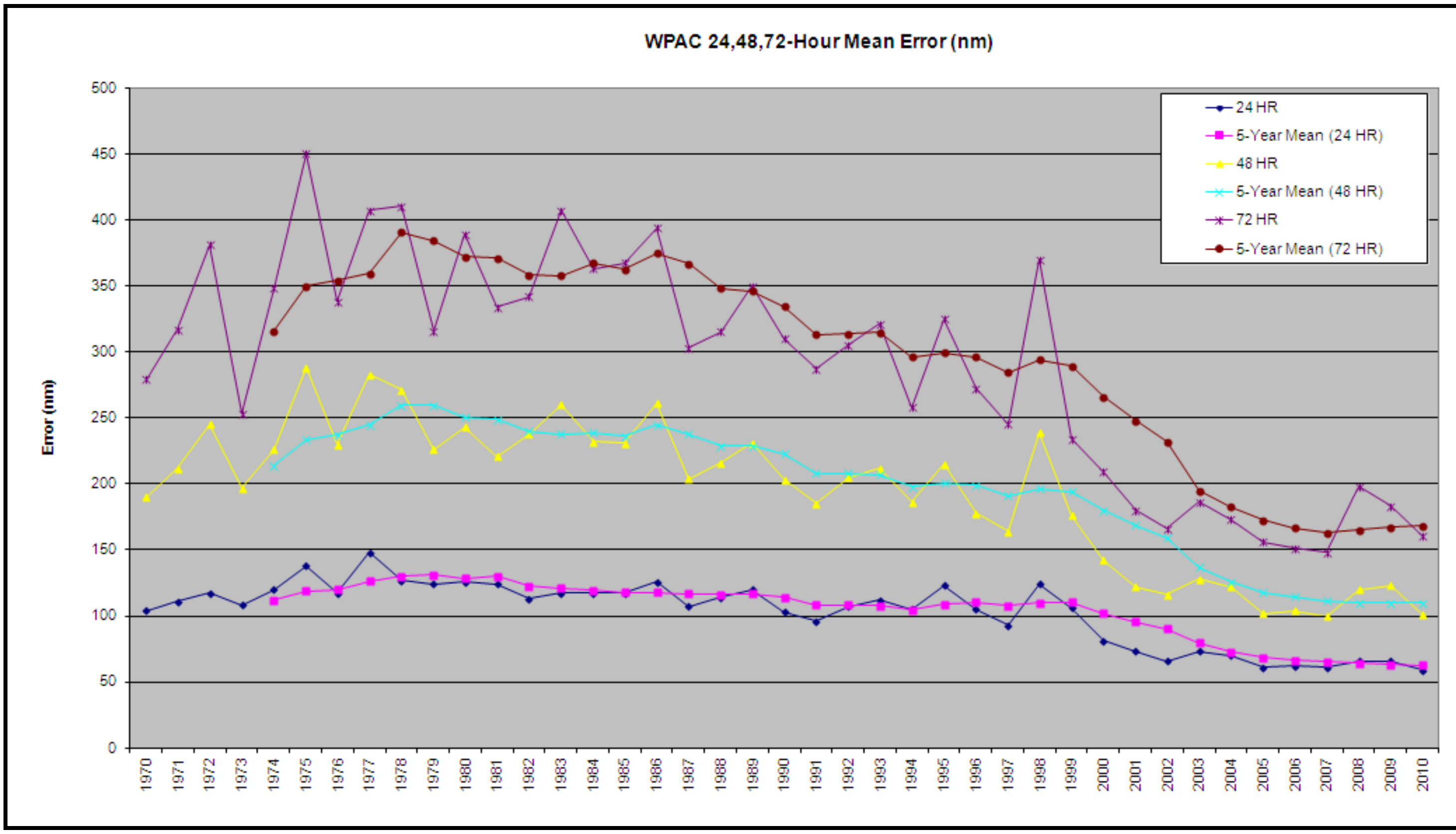


Figure 6-2. Graph of JTWC forecast errors and five year running mean errors for the western North Pacific at 24, 48, and 72 hours.

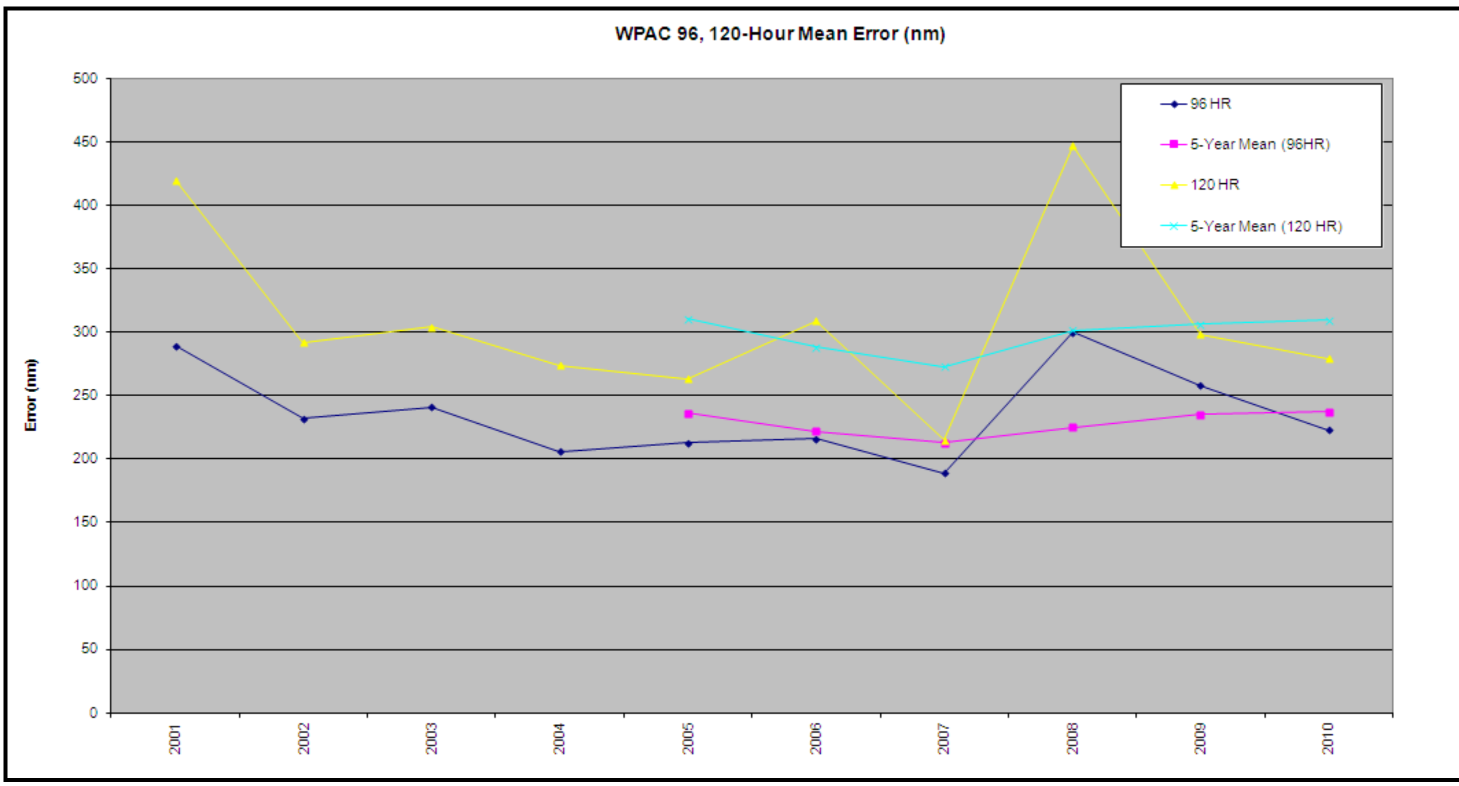


Figure 6-3. Graph of JTWC forecast errors and five year running mean errors for the western North Pacific at 96 and 120 hours.

Table 6-2
MEAN FORECAST TRACK ERRORS (NM) FOR NORTH INDIAN OCEAN
TROPICAL CYCLONES FROM 1985-2010

	24-HOUR				48-HOUR				72-HOUR				96-HOUR				120-HOUR			
YEAR (Notes)	Cases	Mean Error	Cross Track Mean Error	Along Track Mean Error	Cases	Mean Error	Cross Track Mean Error	Along Track Mean Error	Cases	Mean Error	Cross Track Mean Error	Along Track Mean Error	Cases	Mean Error	Cross Track Mean Error	Along Track Mean Error	Cases	Mean Error	Cross Track Mean Error	Along Track Mean Error
1985	30	122	102	53	8	242	119	194	0											
1986	16	134	118	53	7	168	131	80	5	269	189	180								
1987	54	144	97	100	25	205	125	140	21	305	219	188								
1988	30	120	89	63	18	219	112	176	12	409	227	303								
1989	33	88	62	50	17	146	94	86	12	216	164	11								
1990	36	101	85	43	24	146	117	67	17	185	130	104								
1991	43	129	107	54	27	235	200	89	14	450	356	178								
1992	149	128	73	86	100	244	141	166	62	398	276	218								
1993	28	125	87	79	20	198	171	74	12	231	176	116								
1994	44	97	80	44	28	153	124	63	13	213	177	92								
1995	47	138	119	58	32	262	247	77	20	342	304	109								
1996	123	134	94	80	85	238	181	127	58	311	172	237								
1997	42	119	87	49	29	201	168	92	17	228	195	110								
1998	55	106	84	51	34	198	135	106	17	262	188	144								
1999	41	79	59	38	22	184	130	116	10	374	309	177								
2000	24	61	47	26	16	85	69	37	1	401	399	38								
2001	41	61	40	37	31	115	71	71	22	166	44	154								
2002	30	84	41	63	18	137	92	83	10	185	92	133								
2003	37	108	66	69	31	196	115	132	7	354	210	252								
2004	46	81	53	52	36	140	95	85	9	173	144	86								
2005	67	62	41	40	49	116	71	73	18	118	35	109								
2006	19	64	37	44	13	92	58	60	0		-	-								
2007	38	61	38	36	23	94	56	65	10	140	92	93								
2008	59	70	46	44	38	99	71	55	24	127	94	127								
2009	25	93	42	74	10	206	79	169	1	387	102	373	(1)							
2010	63	52	31	33	42	90	67	44	22	170	116	84	11	332	175	259	6	587	154	545
Avg (1985-2010)	47	99	70	55	30	170	117	97	16	267	184	151								
5Yr Avg	41	68	39	46	25	116	66	79	11	206	101	169								

(1) JTWC extended warning period from 72hrs to 120hrs in 2010. 96-hour and 120-hour data is not available prior to 2010.

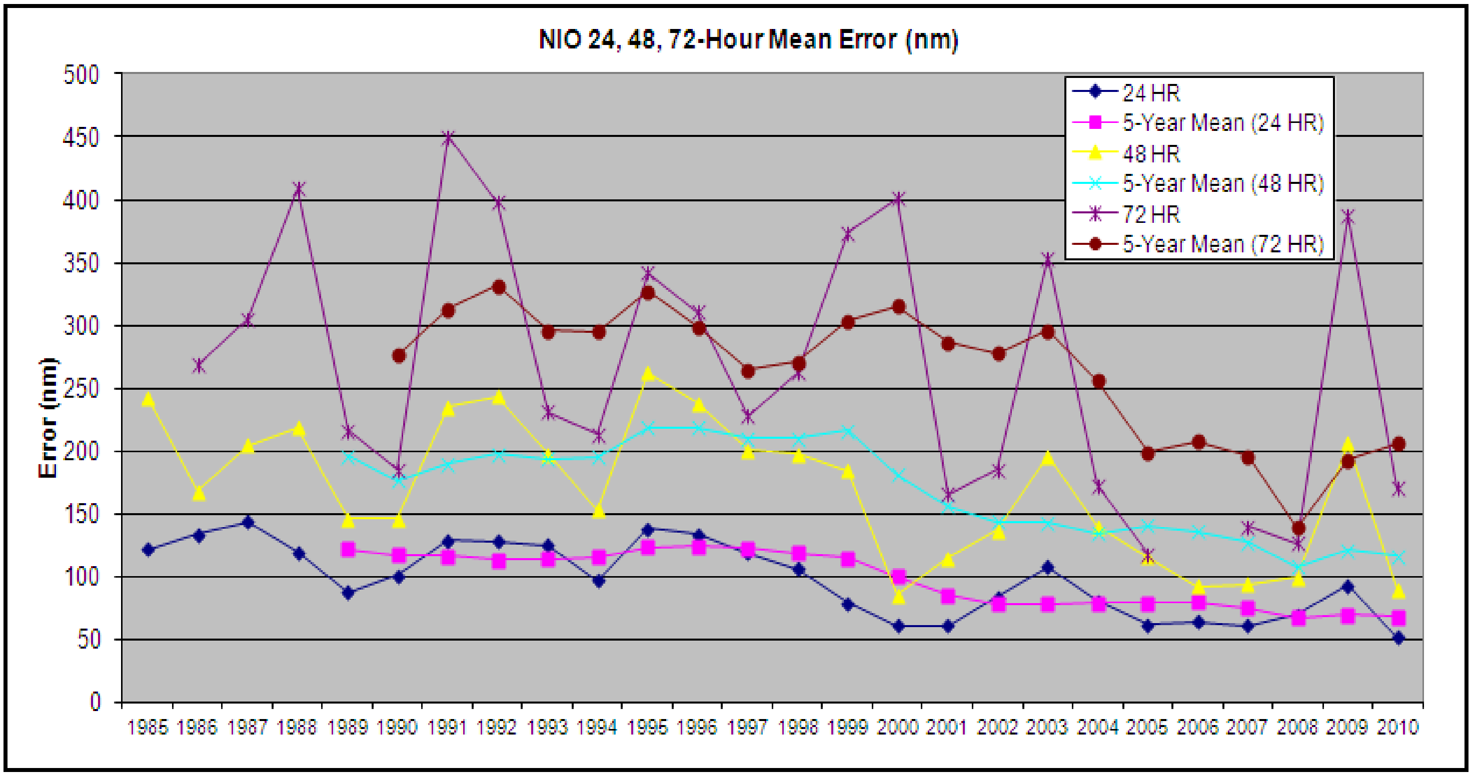


Figure 6-4. Graph of JTWC forecast errors and five year running mean errors for the north Indian Ocean at 24, 48, and 72 hours.

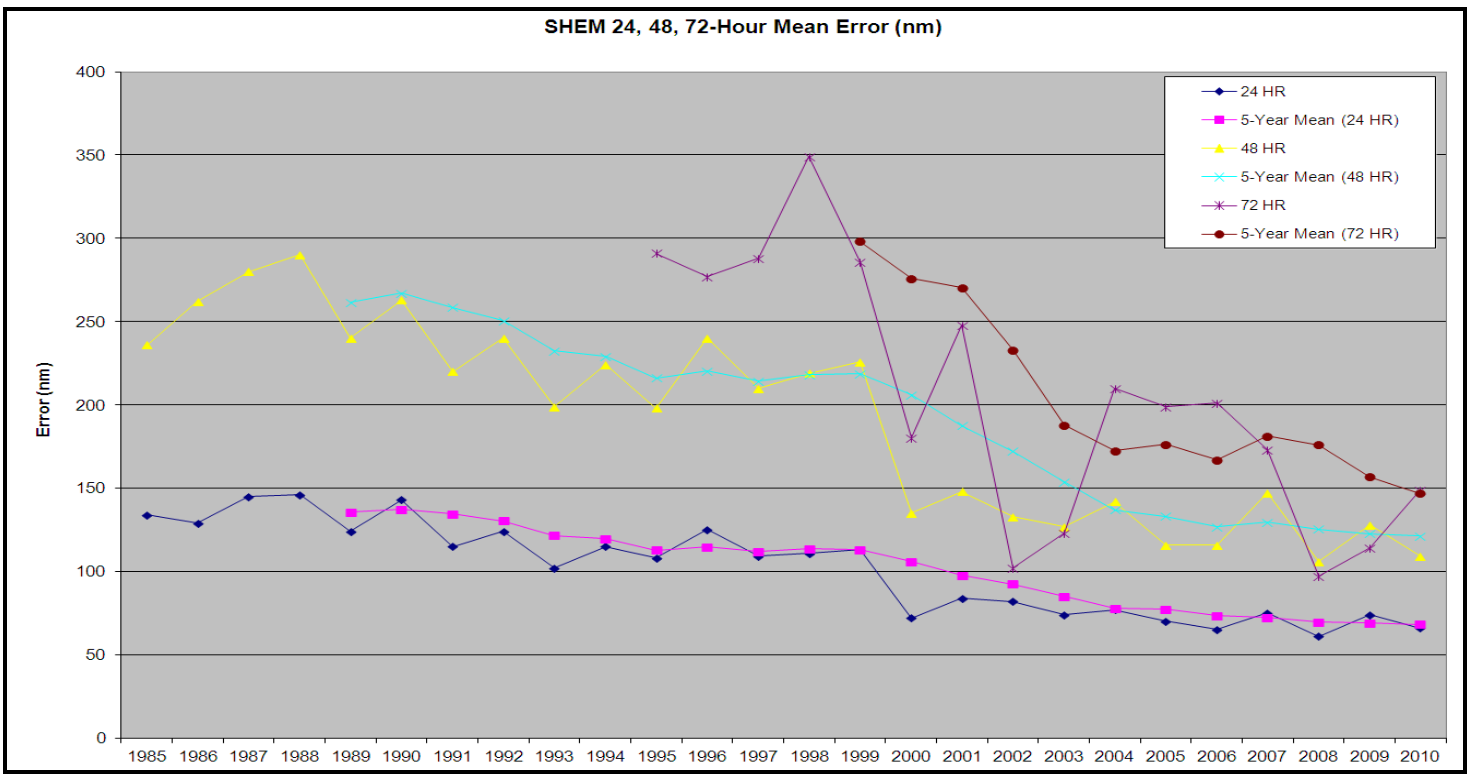


Figure 6-5. Graph of JTWC forecast errors and five year running mean errors for the Southern Hemisphere at 24, 48, and 72 hours.

TABLE 6-3
MEAN FORECAST ERRORS (NM) FOR SOUTHERN HEMISPHERE TROPICAL CYCLONES 1985 - 2010

	24-Hour				48-Hour				72-Hour				96-Hour				120-Hour			
Year (Notes)	Cases	Mean Error	Cross Track Mean Error	Along Track Mean Error	Cases	Mean Error	Cross Track Mean Error	Along Track Mean Error	Cases	Mean Error	Cross Track Mean Error	Along Track Mean Error	Cases	Mean Error	Cross Track Mean Error	Along Track Mean Error	Cases	Mean Error	Cross Track Mean Error	Along Track Mean Error
1985	257	134	79	92	193	236	132	169												
1986	227	129	77	86	171	262	164	169												
1987	138	145	90	94	101	280	138	153												
1988	99	146	83	98	48	290	144	246												
1989	242	124	73	84	186	240	136	166												
1990	228	143	74	105	177	263	152	178												
1991	231	115	69	75	185	220	129	152												
1992	230	124	64	91	208	240	129	177												
1993	225	102	57	74	176	199	114	142												
1994	345	115	68	77	282	224	134	147												
1995	222	108	55	82	175	198	108	144	53	291	190	169								
1996	298	125	67	90	237	240	129	174	46	277	133	221								
1997	499	109	72	82	442	210	135	163	150	288	175	248								
1998	305	111	52	85	245	219	108	169	81	349	171	261								
1999	322	113	64	80	245	226	132	159	59	286	164	198								
2000	313	72	45	47	245	135	86	84	58	180	139	94								
2001	147	84	44	61	113	148	86	105	11	248	197	133								
2002	200	82	43	60	146	133	75	93	5	102	41	91								
2003	279	74	37	57	221	127	68	90	37	123	54	99								
2004	277	77	45	52	233	142	89	92	47	210	102	162								
2005	214	70	44	44	170	116	77	72	41	199	117	136								
2006	191	65	37	46	140	116	69	79	32	201	101	151								
2007	186	74.9	41	52	131	147.2	80	105	3	173.1	146	73								
2008	269	61	38	40	211	106	64	72	27	97	53	65								
2009	166	74	42	51	118	128	74	89	14	114	89	54	(1)							
2010	206	66	40	45	161	109	67	57	125	149	76	109	89	207	117	145	64	276	159	191
Avg (1985-2010)	243	102	58	71	191	191	108	133	49	205	122	142								
5Yr Avg	204	68	40	47	152	121	71	80	40	147	93	90								

(1) JTWC extended warning period from 72hrs to 120hrs in 2010. 96-hour and 120-hour data is not available prior to 2010.